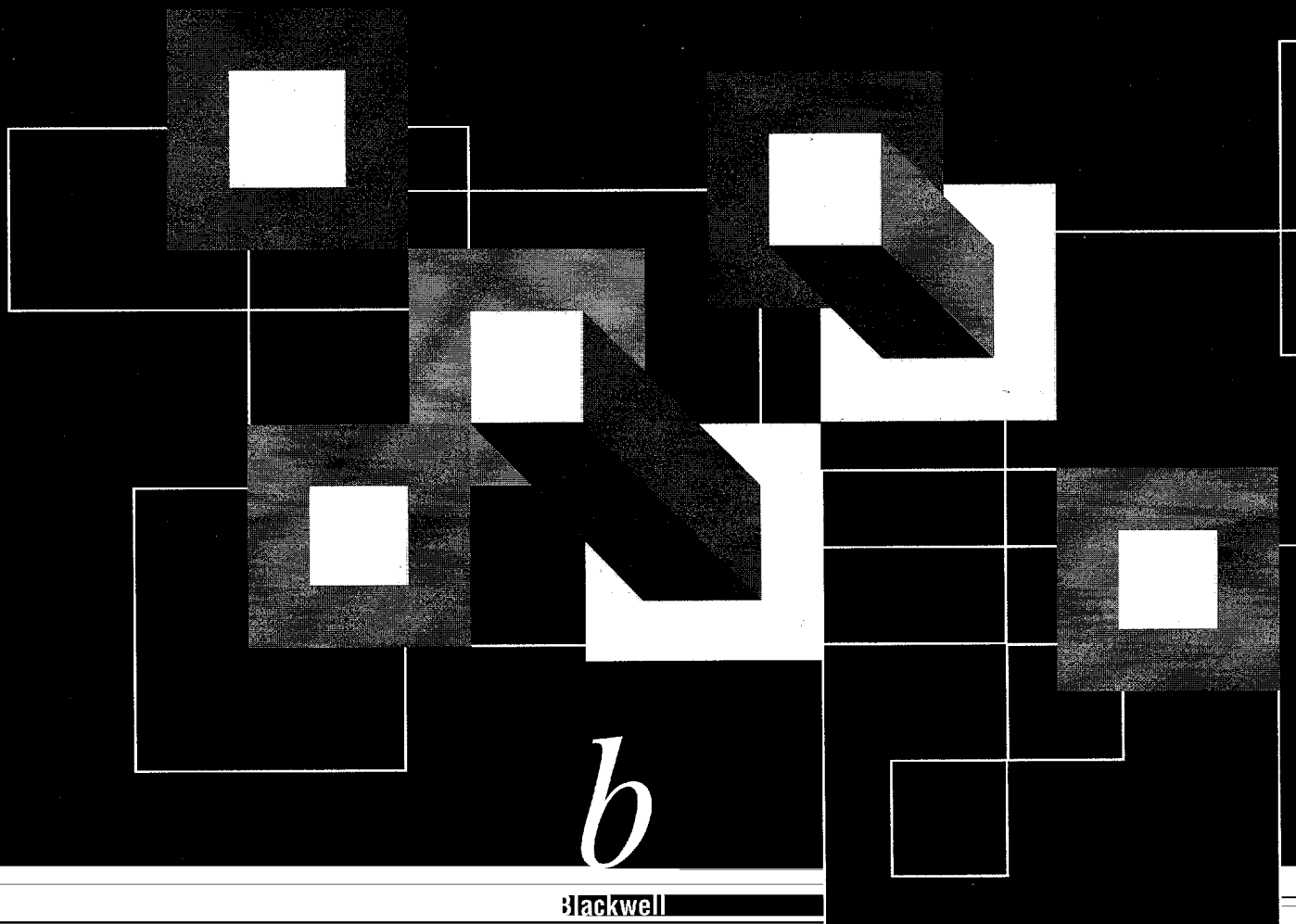


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# THE CONSTRUCTION OF BUILDINGS

*Volume 2*

FIFTH EDITION

**R. BARRY**

*Architect*

WINDOWS – DOORS – STAIRS – FIRES, STOVES and  
CHIMNEYS – INTERNAL FINISHES and  
EXTERNAL RENDERING

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# Preface

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Since publication of the first volume of *The Construction of Buildings* in 1958, the five volume series has been used by both lecturers and students of architecture, building and surveying, and by those seeking guidance for self-build housing and works of alteration and addition.

In this latest revision to Volume 2 a wide right hand column of text has been adopted to facilitate the inclusion of smaller diagrams in the left hand column and larger diagrams within the text column so that, wherever possible, the diagram is adjacent to the relevant text for ease of reference. Bold subheadings in the left hand column provide a quick reference for the reader.

Volume 2 deals with windows, doors, stairs, fires and chimneys, and finishes. The use of the revised page layout has provided a way of emphasising functional requirements such as daylight as the prime function of a window. The introduction and emphasis of thermal resistance as a function has of recent years taken precedence to the extent that the prime function of admission of daylight has been relegated to a minor need. In this revision it is hoped that daylight has reasserted itself as a prime function.

Through a rearrangement of the text and the new page layout it has been possible to give due weight to the prime functions of the elements of building.

The new edition has been updated as necessary to include relevant changes in regulations and practice, as well as a thoroughgoing revision of the text on plastering to take account of the current widespread use of gypsum plaster as an internal wall and ceiling finish.

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# Acknowledgements

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My thanks to Ross Jamieson for redrafting my original drawings and to Mrs Sue Moore for advice and help in the new page layout.

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# 1: Windows

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## FUNCTIONAL REQUIREMENTS

### Daylight

The primary function of a window is:

Admission of daylight

A window is an opening formed in a wall or roof to admit daylight through some transparent or translucent material fixed in the window opening. This primary function of a window is served by a sheet of glass fixed in a frame in the window opening. This simple type of window is termed a fixed light or dead light because no part of the window can be opened.

As the window is part of the wall or roof envelope to the building, it should serve to exclude wind and rain, and act as a barrier to excessive transfer of heat, sound and spread of fire in much the same way that the surrounding wall or roof does. The functional material of a window, glass, is efficient in admitting daylight and excluding wind and rain but is a poor barrier to the transfer of heat, sound and the spread of fire.

### Ventilation

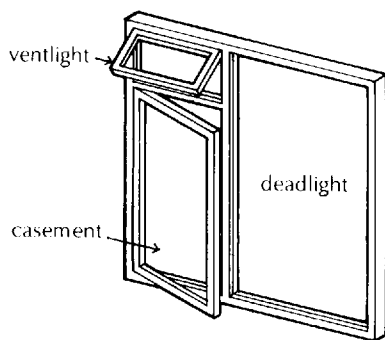


Fig. 1 Casement window.

The traditional window is usually designed to ventilate rooms through one or more parts that open to encourage an exchange of air between inside and outside. Ventilation is not a necessary function. Ventilation can as well be provided through openings in walls and roofs that are either separate from windows or linked to them to perform the separate function of ventilation. The advantage of separating the functions of daylighting and ventilation is that windows may be made more effectively wind and weathertight and ventilation can be more accurately controlled. An advantage of the opening parts of windows is as a means of cleaning the outside of glass, in windows above ground, from inside.

Figure 1 is an illustration of a casement window which combines a top hung ventlight, and side hung casement with a fixed light (deadlight). The fixed or deadlight provides the maximum area of glass for admission of daylight and the ventlight and casement means of ventilation and cleaning glass from inside. The clearance gaps around the ventlight and casement to allow them to open, need rebated frame members and weatherseals to serve as barriers to wind and rain.

### DAYLIGHT

The prime function of a window is to admit adequate daylight for the efficient performance of daytime activities. Good sense dictates tak-

ing the maximum advantage of this free source of illumination when the modern alternative, electric light, is so extravagantly wasteful of natural fuel sources and grossly expensive.

## **Quantity of daylight**

The quantity of light admitted depends in general terms on the size of the window or windows in relation to the area of the room lit, and the depth inside the room to which useful light will penetrate depends on the height of the head of windows above floor level. Common sense and observation suggest that the quantity of daylight in rooms is proportional to the area of glass in windows relative to floor area and this is confirmed by measurement.

## **Intensity of daylight**

The intensity of daylight at a given point diminishes progressively into the depth of the room away from windows. For general activity purposes, such as in living rooms, an adequate overall level of daylight illumination is sufficient, whereas a minimum level of illumination in a particular area is necessary for such activities as drawing.

## **Daylight factor**

Unlike artificial lighting, daylight varies considerably in intensity both hourly and daily due to the rotation of the earth and the consequent relative position of the sun, and also due to climatic variations from clear to overcast skies. In order to make a prediction of the relative level of daylight indoors, it is necessary to make an assumption. In Britain and north-west Europe it is current practice to calculate daylight in terms of a 'daylight factor' which is the ratio of internal illumination to the illumination occurring simultaneously out of doors from an unobstructed sky, rather than using the absolute value, that is lux, commonly used for artificial lighting. In the calculation of the daylight factor it is assumed that the illumination from an unobstructed sky, in the latitude of Britain, is 5000 lux and that a daylight factor of 2% means that 2% of the 5000 lux outdoors is available as daylight illumination at a specified point inside.

The assumption of a standard overcast sky, which represents the condition of poor outdoor illumination that may occur in autumn, winter and spring in northern Europe, is taken as a minimum standard on which to make assumptions. The term 'unobstructed sky' defines the illumination available from a hemisphere of sky free of obstructions such as other buildings, trees and variations in ground level, a condition that rarely occurs in practice.

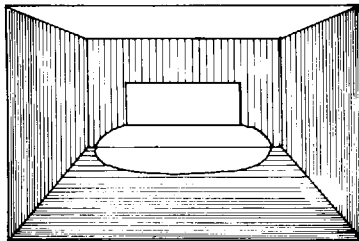
The concept of a daylight factor has the advantage that it is a comparative value of the intensity of daylight indoors at different points so that even though the intensity of daylight outdoors will vary, the relative indoor intensity will remain more or less the same. The daylight factor concept provides a better indication of the subjective impression of daylight than would be the case were an absolute



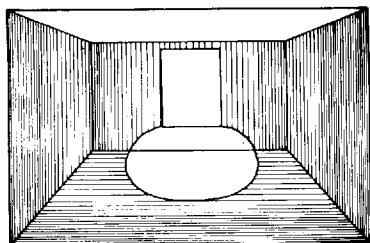
**Table 1** Recommended average daylight factors.

| Building type | Location     | Daylight factor |
|---------------|--------------|-----------------|
| Dwellings     | Living rooms | 1.5             |
|               | Bedrooms     | 1               |
|               | Kitchens     | 2               |
| Work places   | Offices      | 5               |
|               | Libraries    |                 |
|               | Schools      |                 |
|               | Hospitals    |                 |
|               | Factories    |                 |
| All buildings | Residential  | 2               |
| All buildings | Entrances    | 2               |
|               | Public areas |                 |
|               | Stairs       |                 |

Taken from DD73: 1982.

**Fig. 2** Long low window.

## Daylight penetration

**Fig. 3** Tall narrow window.

value given. In the assumption of a standard overcast sky the effect of direct sunlight is excluded. The International Commission on Illumination (CIE) defines daylight factor as 'the ratio of the daylight illumination at a given point on a given plane due to the light received directly or indirectly from a sky of assumed or known luminance distribution, to the illumination on a horizontal plane due to an unobstructed hemisphere of this sky. Direct sunlight is excluded for both values of illumination'.

The intensity of illumination or luminance of the standard sky is assumed to be uniform to facilitate calculation of levels of daylight. In practice sky luminance varies, with luminance at the horizon being about one third of that at the sun's zenith. Average daylight factors for various activities are given in Table 1.

Where artificial illumination is used to supplement daylighting it is often practice to determine a working level of illumination in values of lux and convert this value to an equivalent daylight factor by dividing the lux value by 50 to give the daylight factor. For example, a lux value of 100 is equivalent to a daylight factor of 2. The average daylight factor in side-lit rooms is roughly equal to one fifth of the percentage ratio of glass to floor area.

In a room with a window on one long side, as illustrated in Fig. 2, with no external obstructions and a room surface reflectance of 40%, where the glass area is one fifth or 20% of floor area, the average daylight factor will be 4 and the minimum about half that figure. Conversely, to obtain an average daylight factor of, say 6, in a room with a floor area of  $12\text{m}^2$ , a glass area of about  $6 \times 12 \times 5 / 100 = 3.6\text{m}^2$  will be required. This broad average calculation is generally sufficient when used for general activity purposes such as in living rooms, and it is an adequate base for preliminary assumptions of window to floor area which can be adjusted later by a more accurate calculation of the light required for activities in which the lighting is critical.

A broad measure of the penetration of useful daylight into rooms is, taking an average figure of 2 as a daylight factor, the depth of penetration in line with the centre of windows as equal to the height of the window head above floor level, as illustrated in Fig. 3.

The quantity and quality of daylight illumination in side-lit rooms is affected to an extent by the light reflected from floors, walls and ceilings which will augment light coming directly through windows. Plainly the effect of this reflected light will be affected by the colour and texture of the reflective surfaces. Similarly some daylight, reflected from pavings and nearby external obstructions such as buildings and trees, will to an extent add to both the direct penetration of light and internally reflected light.

## Reflected light

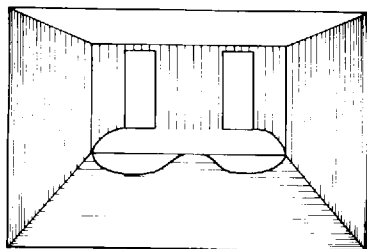


Fig. 4 Tall narrow windows.

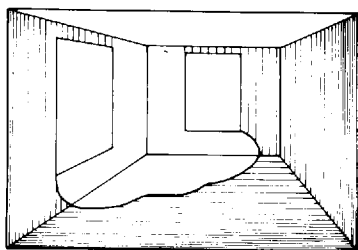


Fig. 5 Windows in adjacent walls.

In the assumption of a daylight factor, account is taken of the contribution of what is termed 'the internally reflected component' and the 'externally reflected component' of indoor daylight illumination. Obviously the extent to which both the internal and external reflected light adds to or augments the indoor lighting will be least with low levels of overall daylight and dark, rough textured reflective surfaces, and will be most with higher levels of overall daylight and light coloured, smooth textured reflective surfaces.

The shape, size and position of windows affect the distribution of daylight in rooms and the view out. Tall windows give a better penetration of light than low windows, as illustrated in Fig. 4. The tall, narrow windows illustrated in Fig. 4 provide good penetration of daylight into rooms which may be augmented by the reflection from white painted, splayed internal reveals to the windows. Some distribution of daylight between the windows is provided by the overlap of penetration between the two windows.

Separate windows give a less uniform distribution of light than continuous windows. Windows in adjacent walls give good penetration and reduce glare by lighting the area of wall surrounding the adjacent window, as illustrated in Fig. 5. Windows in opposite walls of narrow rooms give good penetration and reduce glare by lighting opposite walls around windows.

In the calculation of daylight factors it is usual to determine the quantity of daylight falling on a horizontal working plane 850 mm above floor level to correspond with the height of working surfaces such as tables, desks or benches.

## Area of glass

It is advantageous to be able to make a reasonably accurate estimate of the area of glass in windows, necessary to provide the average daylight factor recommended for the activity for which the room or space is designed. The averaged or average daylight factor represents the overall visual impression of the daylighting in a room or space taking into account the distribution of light in the space and the effect of reflected light.

The penetration and distribution of daylight in rooms will increase by internal reflection of light from ceilings, walls and floors. Where the reflectance from light coloured smooth surfaces is good, the net area of glass required to provide a daylight factor of 2, will be 1.28 m<sup>2</sup> as compared to 1.60 m<sup>2</sup> where reflectance is low from dark rough surfaces in a room 3 m square with a 3 m ceiling height.

## Calculation of daylight factor

Where daylighting by itself or in combination with artificial lighting is critical for the performance of activities, such as drawing at a fixed point or points in a room, it is necessary to estimate the minimum daylighting available at a point. For this purpose there are a number of aids, such as the artificial sky and the overlays for scale drawings.

An artificial sky provides luminance comparable to the standard overcast sky, through an artificially lit dome which is laid over a scale model of the building in which photometers are used to measure the light available. The graphical aids in the form of overlays include Waldram diagrams, BRS protractors and the dot or pepper pot diagrams of which the dot diagram is the most straightforward to use.

The dot diagram has the appearance of a sheet of paper onto which a pepper pot has deposited grains of pepper, hence the name pepper pot diagram. The grains of pepper, the dots, represent a small proportion of the daylight illumination available at that point. The greater the density of dots the greater the illumination.

### Pepper pot diagram

The pepper pot diagram is a transparent overlay on which dots are printed above a horizontal line representing the horizon. The diagram is drawn to a scale of 1 : 100 as an overlay to drawings to the same scale. Each dot represents 0.1% of the sky component. The overlay shown in Fig. 6 is for daylight through side-lit windows with the CIE standard overcast sky. To use the overlay, draw the outline of a window to a scale of 1 : 100 so that the outline represents the glass area to scale. The diagram is designed to determine the sky component of daylight on a line 3 m back from the window. Place the overlay on the scale elevation of the window with the horizontal line

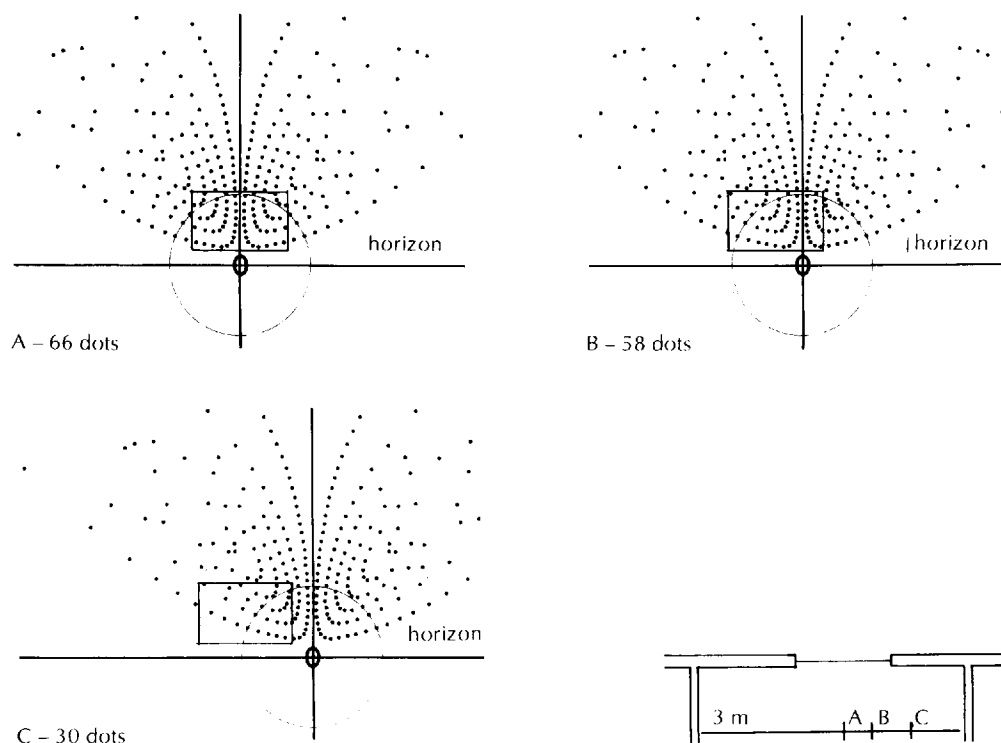


Fig. 6 Sky component.

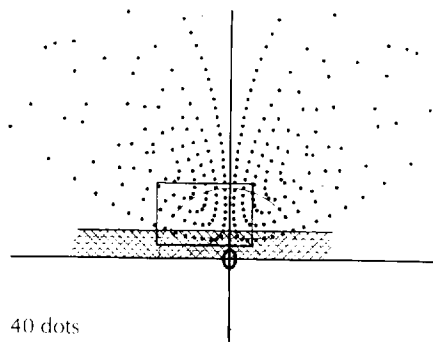


Fig. 7 Sky component.

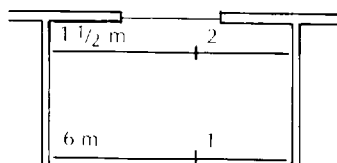
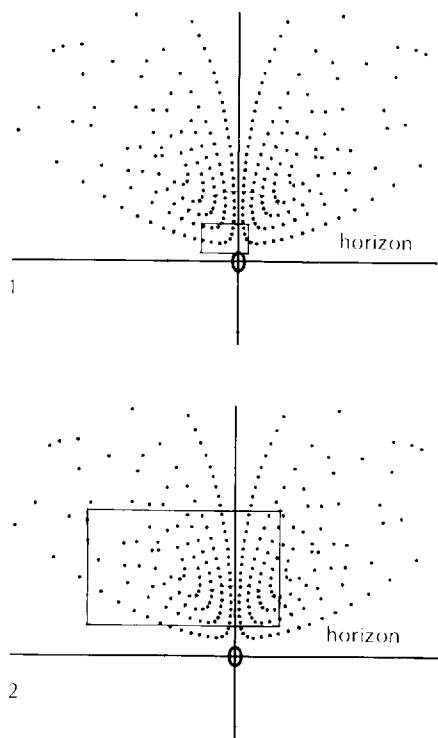


Fig. 8 Sky component.

of the overlay on the line of the working plane, that is 850 mm above the floor, drawn to scale on the window elevation. To determine the sky component at a point 3 m back on the centre of the window, place the vertical line of the overlay on the centre of the window as illustrated in Fig. 6A, then count the dots inside the window outline. The 66 dots inside the window outline represent a sky component of 66/10, that is 6.6% at a point 3 m back from the centre of the window on the working plane.

To find the sky component on the line 3 m back from the window at other points, slide the overlay horizontally across the window outline until the vertical line of the overlay coincides with the chosen point inside the room, either inside or outside the window outline, as illustrated in Figs 6B and C. Count the dots inside the window outline to determine the sky component at the chosen points.

Where there are obstructions outside windows, such as adjacent buildings, which obscure some of the daylight, the overlay can be used to determine both the loss of light due to the obstruction and the externally reflected component of light due to reflection of light off the obstruction and into the room through the window. A simple example of this is where a long low building will obstruct daylight at a point 3 m inside the room on the centre of the window at the working plane. The outline of the long obstruction is shown in Fig. 7 by the shaded area. The height of the obstruction above the horizon is represented by the height to distance ratio of the obstruction relative to the point on the working plane inside the window. This ratio is 0.1 for each 3 mm above the horizon on the scale drawing of the window. The number of dots inside the window outline above the shaded obstruction gives the sky component as 40% and the number of dots 12 inside the shaded area, the externally reflected component. These dots represent 0.01% of the externally reflected component.

To find the sky component at points on a line other than the line 3 m back from the window drawn to a scale of 1 : 100, it is necessary to adjust the scale of the window outline. If the scale of the window is doubled, it will represent the sky component at points 1.5 m back from the window, and if the scale is halved, 6 m back from the window, as illustrated in Fig. 8 for points on the centre of the window. In adjusting the scale of the window outline it is also necessary to adjust the scale height of the working plane above the floor by doubling or halving the scale as shown in Fig. 8.

The particular use of this diagram is to test the sky component of daylight inside rooms at an early stage in the design of buildings. By the use of window outlines drawn freehand to scale on graph paper, with the overlay, a comparative assessment of the effect of window size and position on the sky component of daylight inside rooms can quickly be made. This will provide a reasonably accurate assessment

of comparative daylight levels in rooms to be used for many activities where the exact level of daylight is not critical.

## **Quality of daylight**

### **Glare**

Glare is defined as 'a condition of vision in which there is discomfort or a reduction in the ability to see significant objects or both, due to an unsuitable distribution or range of luminance, or to extreme contrasts in space or time'. The two distinct aspects of glare are defined as disability glare and discomfort glare.

### **Disability glare**

Disability glare, which is defined as 'glare which impairs the vision of objects without necessarily causing discomfort', is caused when a view of bright sky obscures objects close to the source of glare. An example of this is where a lecturer is standing with his back to a window so that he is obscured by the bright sky behind him. Disability glare can be avoided by a sensible arrangement of the position of windows and people, whose vision of objects might otherwise be obscured.

### **Discomfort glare**

Discomfort glare, defined as 'glare which causes discomfort without necessarily impairing the vision of objects', is created by large areas of very bright sky viewed from inside a building which causes distraction, dazzle and even pain. With vertical windows discomfort glare is caused, in the main, by the contrast between visible sky and the room lighting and this contrast can be usefully reduced by splaying window reveals and painting them a light colour to provide a graded contrast between the bright sky and the darker interior. This 'contrast grading' effect can be used with many window shapes and sizes. With very large windows such as the continuous horizontal strip windows which face southwards, discomfort glare is difficult to avoid owing to the large unbroken area of glazing and here some form of shading device will be required.

The degree of glare can be determined numerically and stated in the form of a 'glare index' from a formula suggested by The Building Research Station.

### **Form and texture**

For the best visual enjoyment of solid objects the direction of light is important in relation to modelling by shadows and for appreciation of texture the quantity and area of the light source has most effect. These known subjective effects are difficult to quantify. It is generally accepted that light from the side is more agreeable than light from above and that side lighting from tall vertical windows provides better modelling of solid objects than large wide side windows. A single bright source of light emphasises texture and gives hard shadows whereas a light from a large diffuse source such as a window gives softer shadows and texture but appreciable modelling of form, and a very large diffuse source, such as rooflighting or overall ceiling

illumination, may cause all but the most coarse texture to disappear and give poor modelling.

## View out

As well as admitting daylight it is generally accepted that windows perform the useful function of providing a view out of buildings as a link with the outside and to provide the variations of interest that stimulate and break the monotony of repetitive tasks. Studies have been made to deduce possible optimum sizes and spacing of windows to provide a view out.

These studies have been inconclusive in detail but have established that the majority of people in sedentary occupations, such as office workers, derive benefit from a view out.

## SUNLIGHT

In the late nineteenth century, concern for what were considered to be the poor living conditions in urban areas of northern European countries turned to the effects of sunlight on health. Early research sought to relate mortality and disease to the availability of sunlight in rooms and the courtyards of, for example, back-to-back dwellings. It is now plain that sunlight is not essential for hygiene, biological or therapeutic purposes. Later research seeking a norm of preference for sunlight in buildings has been inconclusive in determining a chosen minimum amount of sunlight because preferences varied so widely. From all the surveys that have been undertaken it is apparent that the majority preference is for a satisfying view, some sunlight, particularly in living rooms, and visual privacy.

In this country, where the norm seems to be overcast dull skies, the cheerful aspect of sunlight is cherished. The fashion in recent years for large windows, sometimes called picture windows, reflects the wish of a mainly indoor people to enjoy sunlight and a view. With the recent increase in the cost of fuels there has been a move towards smaller windows to reduce heat losses and solar heat gain that can cause discomfort in the summer. The pendulum of fashion that has swung from maximum glass area towards minimum glass area has yet to settle towards a sensible mean between the two.

The fashion for large windows and large areas of glass ('curtain walls' in Volume 4), prompted by the comparatively low cost of glass, has changed as glass is no longer a comparatively cheap building envelop material and its disadvantages as a thermal and sound insulator are now more widely known. Nonetheless the subjective preference for sunlight and a view out, and the economic advantage of freely available daylight and controlled solar heat gain, prompt the optimum use of glazing compatible with reasonable thermal and sound insulation.

A Code of Practice (since withdrawn) recognised the preference for sunlight in rooms by setting out recommended minimum periods of

sunlight penetration. A Draft for Development included criteria for the insolation of dwellings, giving recommendations for the orientation of rooms and therefore the planning and siting of buildings. These recommendations did not include recommendations for the size and shape of windows.

## Insolation

The criteria for insolation (exposure to sun's rays) suggest minimum possible or probable standards for sunlight on buildings as a guide in the design and layout of dwellings to gain the advantage of both sunlight and solar heat.

## Colour fading

Sunlight causes most coloured materials to fade. It is the ultra-violet radiation in sunlight that has the most pronounced effect on coloured materials by causing the chemical breakdown of the colour in such materials as textiles, paints and plastics by oxidative bleaching, that is fading. The bleaching effect is more rapid and more noticeable with bright colours. The lining of colour-sensitive curtains on the window side with a neutral coloured material and the use of window blinds are necessary precautions to prolong the life of colour-sensitive materials.

## Solar heat gain

In the calculation of energy use in maintaining equable indoor temperature and necessary insulation to limit heat loss, described later, allowance is made for solar heat gain. A calculation is made of the probable solar heat gain as part of the necessary energy input to maintain indoor temperature.

Because of the orbit of the earth round the sun and the simultaneous rotation of the earth on its axis inclined at  $22.5^\circ$  to the plane of orbit, the apparent movement of the sun around the earth varies throughout the solar year and penetration of sunlight through windows varies in intensity and depth. To plot the penetration of sunlight throughout the year would be a lengthy and tedious task. For the majority of buildings in the temperate climate of Britain such an exercise is unnecessary, except where it is anticipated that bright sunlight could cause discomfort or danger in performing tasks in static positions inside rooms or buildings or where solar heat gain might cause considerable discomfort or uneconomic use of internal heat.

There are geometric sunpath diagrams that may be used to check whether the face of a building will receive sunlight and when, the depth of penetration and the resultant patch of sunlight on room surfaces and the shading by obstructions at various times of the day throughout the year. An example of the use of 'gnomonic' projections to deduce sunlight patterns on room surfaces throughout the day is shown in Fig. 9. The diagram shows the floor of a single room with a south east facing window and the walls on which the sun will shine at half hourly intervals on 15 January.

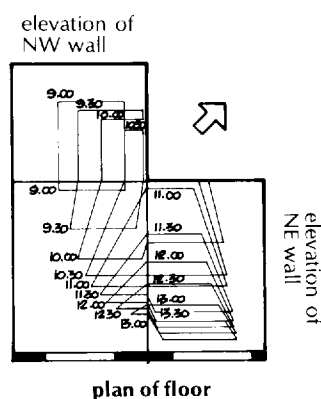


Fig. 9 Gnomonic projection.

These sunpath diagrams may also, with suitable overlays, be used to predict the intensities of direct and diffuse solar radiation and the consequent solar heat gain. Recently a computer program has become available that will predict energy consumption for heat loss and heat input calculations and will make allowances for the variable of solar heat gain through windows so that modifications in both window sizes and the heat input from heating plant can be adjusted at the design stage. This facility has taken over the tedium of calculation by sunpath diagrams.

## Sun controls and shading devices

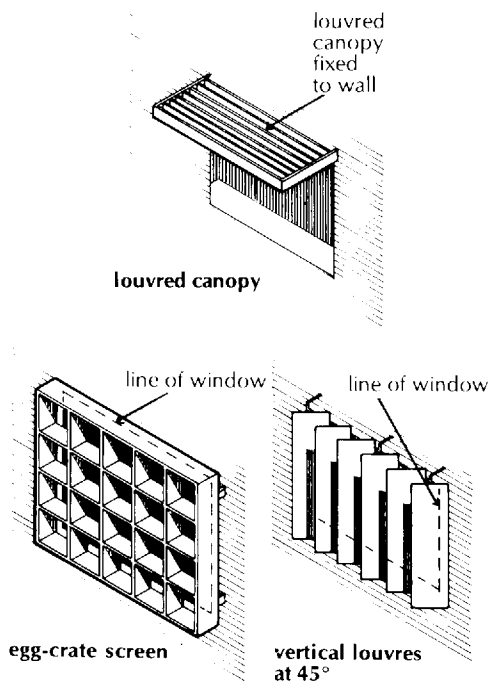


Fig. 10 Shading devices.

The traditional temperate climate means of controlling the penetration of sunlight to rooms are the slatted wooden louvre shutters common to the French window, and awnings and blinds that can be opened or closed. These controls are adjustable between winter and summer conditions, graduated from no shade and the maximum penetration of daylight in winter through some shade and some daylight to full shading in high summer.

Fixed projections above windows, such as canopies and balconies, are also used as sun controls in temperate climates to provide shade from summer sun while allowing penetration of sun at other times of the year for the advantage of sunlight and solar heat gain.

In tropical and semi-tropical climates fixed sun controls or shading devices in the form of canopies, screens or louvres are used, as illustrated in Fig. 10.

Sun controls serve to exclude sunlight to reduce glare or solar heat gain or both. To control and reduce solar heat gain sun controls should be fixed outside windows where they absorb solar heat which is then dissipated to the outside, whereas where sun controls are fitted internally, e.g. blinds, the solar heat they absorb is dissipated inside the room.

## VENTILATION

Up to the middle of the twentieth century the principal means of heating was by solid fuel burning fires and stoves. The considerable intake of air required for combustion of wood, coal or coke in fires and stoves at the same time provided more than adequate changes of air for the ventilation of rooms, to the extent that cold draughts of air drawn in during winter months through cracks around opening windows and doors caused discomfort. At the time the concern was to control draughts of incoming cold air rather than considerations of ventilation. With the introduction of oil and gas fired central heating boilers, it was practical to heat the whole of buildings from one



central boiler that drew air for combustion directly from outside and so reduced draughts of cold air from outside. The rapidly increasing use of oil and gas from the middle of the twentieth century prompted concern for the need to conserve the limited sources of energy. Initially regulations required minimum standards of insulation in the roofs and walls of new buildings.

The current trend towards conservation of energy, by more efficient use of insulation against excessive transfer of heat, has led to the installation of double glazing to windows in both new and old buildings and the fitting of effective weather-stripping around the opening parts of windows and doors to reduce draughts of cold air entering the building. Open fires are uncommon in modern buildings and many open fireplaces in older buildings have been sealed, so blocking flues that provided some ventilation. This means that there is less provision for permanent changes of air. The air in rooms may become 'stuffy' and uncomfortable and at worst unhealthy.

So that there is some provision for natural ventilation the Building Regulations now require means of ventilation to habitable rooms, kitchens, bathrooms and sanitary accommodation to provide air change by natural or mechanical ventilation and also to reduce condensation in rooms where warm, moisture vapour laden air may condense to water. The provisions are for opening windows and vents and some mechanical ventilation to kitchens, bathrooms and sanitary accommodation.

## Air changes

For the comfort and well-being of people it is necessary to ventilate rooms by allowing a natural change of air between inside and outside or to cause a change by mechanical means. The necessary rate of change will depend on the activities and numbers of those in the room. The rate of change of air may be given as air changes per hour, as for example one per hour for living and up to four for work places, or as litres per second as a more exact requirement where mechanical ventilating is used, because it gives a clear indication of the size of inlets, extracts, ducts and pressures required.

The size of a ventilating opening, by itself, gives no exact indication of the likely air change as the ventilating effect of an opening depends on air pressure difference between inside and outside and the size of the opening or openings through which air will be evacuated to cause air flow. The actual ventilating effect of a window, by itself, is unpredictable as it will, when open, in all likelihood act to intake and extract air at the same time.

The rate of exchange of air will depend on variations between inside and outside pressure and heat, and the size and position of other openings in the room such as doors and open fireplaces that may play a part in air exchange. An open window, by itself, may well not

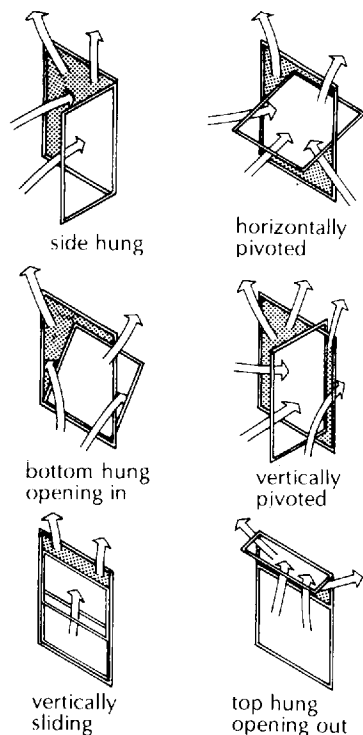


Fig. 11 Ventilation.

thoroughly ventilate a room. For thorough ventilation, that is complete air change, circulation of air is necessary between the window and another or other openings distant from the window. otherwise pockets of stagnant air may be undisturbed in those parts of the room distant from the window.

Ventilation air changes are necessary to minimise condensation which is caused when warm airborne moisture vapour precipitates in droplets on cold surfaces such as glass and metal. By ventilating, the warm moist air is exchanged with drier air that is less likely to cause condensation.

The probable ventilating action of the various types of window in comparatively still air conditions due to the exchange of warmed inside and cooler outside air is illustrated in Fig. 11.

The traditional method of ventilating is through opening lights in windows. The advantage of opening lights is that they can be opened or closed to suit the individual choice of the occupant of rooms regardless of notional optimum rates of air change for comfort and well being. The facility of 'flinging wide the casement to fresh air' has long been cherished and is unlikely to be abandoned in the foreseeable future. The disadvantages of opening lights are that they are difficult to open just sufficient for ventilation without letting in cold draughts or gusts of wind; the necessary clearance gaps around opening lights may allow an excess of air leakage and rain leakage; the necessary framing around them reduces the area available for glass; and they present a high security risk.

For control of ventilation the vertically sliding window is the most efficient as it can be operated to provide either small gap ventilation between meeting rails and sashes and frame, or opened to nearly half its total area, and the degree of opening can be closely controlled between these extremes. Side-hung casements are less efficient as they are difficult to open to provide closely controlled gap ventilation around the three open edges of the sash and for this reason top-hung ventilights are often used.

Top-hung lights are reasonably efficient but less readily controlled than the sliding sash in that there is the likelihood of both the extraction of air from below and the intake of air from the sides. Bottom-hung windows will operate to encourage the intake of air over them and extraction from the sides. Pivot windows are generally less efficient in the control of ventilation as they are difficult to open sufficiently to prevent variable gusts of wind and cold draughts being directed in at low level. In addition large pivot windows, when open, may be distorted by heavy gusts of wind and may then be difficult to close tight unless there is a mechanism to lock the sash shut at several points. Horizontally pivoted windows should be capable of being locked shut both top and bottom else the top, opening in part of the

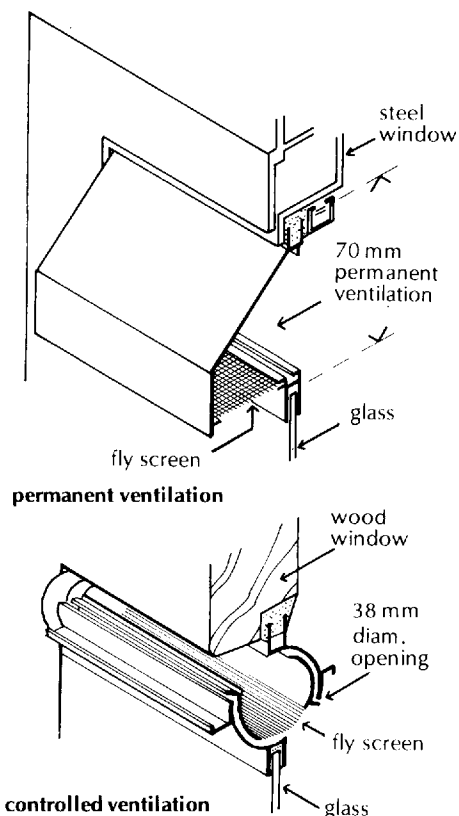


Fig. 12 Ventilators.

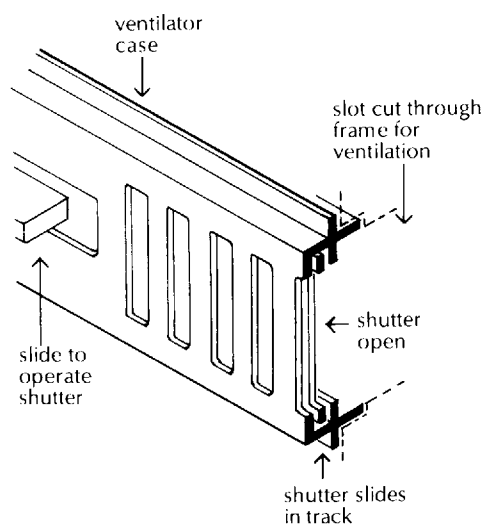


Fig. 13 Trickle ventilator.

sash, may be forced in by high winds and allow considerable air seepage.

Apart from the wish to fling windows wide open there is every reason to dispense with opening lights and replace them with ventilators designed to control air movement only. These ventilators can be included in windows either in place of part of the glass or as part of the window head or cill construction, or they may be fixed separate from the windows. For ventilation alone these ventilators need only small apertures that can be opened and closed by means of simple 'hit and miss' control or hinged or pivoted flaps operated by cord and pulley or winding gear.

The ventilators illustrated in Fig. 12 are fixed in the rebated glazing opening above the glass. The ventilator shown in the upper diagram is for permanent ventilation and that in the lower diagram for controlled ventilation.

Approved Document F gives practical guidance to meeting the requirements of the Building Regulations for the provision of means of ventilation for dwellings. The requirements are satisfied for habitable rooms, such as living rooms and bedrooms when there are:

- (1) For rapid ventilation – one or more ventilation openings, such as windows, with a total area of at least  $\frac{1}{20}$  of the floor area of the room, with some part of the ventilating opening at least 1.75 m above the floor.
- (2) For background ventilation – a ventilation opening or openings having a total area of not less than 4000 mm<sup>2</sup>, which is controllable, secure and located so as to avoid undue draughts, such as the trickle ventilator, illustrated in Fig. 13.

For kitchens the requirements are satisfied when there is both:

- (1) Mechanical extract ventilation for rapid ventilation, rated as capable of extracting at a rate of not less than 60 litres per second (or incorporated within a cooker hood and capable of extracting at 30 litres a second) which may be operated intermittently for instance during cooking, and
- (2) Background ventilation, either by a controllable and secure ventilation opening or openings having a total area of not less than 4000 mm<sup>2</sup>, located so as to avoid draughts, such as a trickle ventilator or by the mechanical ventilation being in addition capable of operating continuously at nominally one air change per hour.

For bathrooms the requirements are satisfied by the provision of mechanical extract ventilation capable of extracting at a rate of not less than 15 litres a second, which may be operated intermittently.

For sanitary accommodation the requirements are satisfied by either:

- (1) Provision for rapid ventilation by one or more ventilation openings with a total area of at least  $\frac{1}{20}$  of the floor area of the room and with some part of the ventilation opening at least 1.75 m above the floor level, or
- (2) Mechanical extract ventilation, capable of extracting air at a rate of not less than three air changes per hour, which may be operated intermittently with 15 minutes overrun.

## **FUNCTIONAL REQUIREMENTS**

As a component part of a wall or roof a window should satisfy the same functional requirements as a wall or roof, namely:

Strength and stability

Resistance to weather

Durability and freedom from maintenance

Fire safety

Resistance to the passage of heat

Resistance to the passage of sound

Security

## **Safety requirements**

Two safety requirements from Parts K and N to the Building Regulations concern the opening parts of windows in buildings other than dwellings.

The requirement in Part K is that measures be taken to prevent people, moving in or about the building, from colliding with open windows. This requirement is met where the projection of a window, either internally or externally, is more than 100 mm horizontally and the lowest part of the projection is more than 2 m above floor or ground.

The requirements in Part N are that windows, skylights and ventilators can be opened, closed or adjusted safely and that there is safe access for cleaning windows.

The requirement for access for operating applies to controls that are more than 1.9 m above floor. The requirement for access of cleaning windows, inside and out, where there is a danger of falling more than 2 m, will be met if provision is made for safe means of access.

## **Strength and stability**

A window should be strong enough when closed to resist the likely pressures and suctions due to wind, and when open be strong and stiff enough to resist the effect of gale force winds on opening lights. A

window should also have sufficient strength and stiffness against pressures and knocks due to normal use and appear to be safe, particularly to occupants in high buildings. A window should be securely fixed in the wall opening for security, weathertightness and the strength and stiffness given by fixings.

## Wind loading

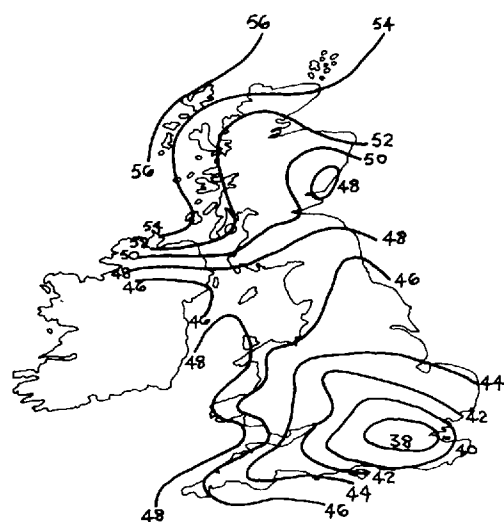


Fig. 14 Basic wind speeds.

The direction and strength of wind fluctuates to the extent that sophisticated electronic equipment is necessary to measure the changes in pressure that occur. To determine the wind pressures that a window is likely to suffer it is convenient to define these as maximum gust speed, averaged over 3 second periods, which are likely to be exceeded on average only once in 50 years. These gust speeds have been measured by the Meteorological Office and plotted as basic wind speeds on a map of the United Kingdom (Fig. 14). The wind speeds are expressed in metres per second rather than miles per hour, the index used in weather reports in the United Kingdom.

To determine probable wind loads on buildings the method given in BS 6262 can be used for buildings that are of simple rectangular shape and up to 10m high from eaves to ground level. The basic wind speed is determined from the map of the United Kingdom (Fig. 14).

The basic wind speed is then multiplied by a correction factor that takes account of the shelter afforded by obstructions and ground roughness as set out in Table 2 to arrive at a design wind speed. The left hand column in Table 2, 'Height above ground', relates to height of window above ground as plainly the higher above ground the less will ground roughness and obstructions provide shelter.

The four categories of protection by obstructions and ground roughness run from 1 with effectively no protection in open country to 4 with maximum protection from surrounding buildings in city centres. A degree of judgement is necessary in selecting the correction category suited to the site of a particular building as the purpose is to select a window construction suited to the most adverse conditions that will occur on average once in 50 years.

The probable maximum wind loading is then obtained from Table 3 by reference to the design wind speed. The wind loading is used to select the test pressure class of window construction necessary and graphs are used to select the required thickness of glass.

Windows are tested in a laboratory to determine test pressure classes; a sample of manufactured windows complete with opening lights and glass is mounted in a frame to represent the surrounding walls. The criterion of success in the pressure test is that after the test the window should show no permanent deformation or other damage and there should be no failure of fastenings.

**Table 2** Correction factors for ground roughness and height above ground.

| Height<br>above<br>ground (m) | Category 1 | Category 2 | Category 3 | Category 4 |
|-------------------------------|------------|------------|------------|------------|
| 3 or less                     | 0.83       | 0.72       | 0.64       | 0.56       |
| 5                             | 0.88       | 0.79       | 0.70       | 0.60       |
| 10                            | 1.00       | 0.93       | 0.78       | 0.67       |

Category 1: Open country; with no obstructions. All coastal areas.

Category 2: Open country; with scattered wind breaks.

Category 3: Country; with many wind breaks; e.g. small towns; city outskirts.

Category 4: Surfaces with large and frequent obstructions; e.g. city centres.

Taken from BS 6262.

**Table 3** Probable maximum wind loading.

| Design wind<br>speed (m/s) | Wind loading<br>(N/m <sup>2</sup> ) | Design wind<br>speed (m/s) | Wind loading<br>(N/m <sup>2</sup> ) |
|----------------------------|-------------------------------------|----------------------------|-------------------------------------|
| 28                         | 670                                 | 42                         | 1510                                |
| 30                         | 770                                 | 44                         | 1660                                |
| 32                         | 880                                 | 46                         | 1820                                |
| 34                         | 990                                 | 48                         | 1980                                |
| 36                         | 1110                                | 50                         | 2150                                |
| 38                         | 1240                                | 52                         | 2320                                |
| 40                         | 1370                                |                            |                                     |

Taken from BS 6262.

## Resistance to weather

To conserve heat and avoid cold draughts it is good practice to design windows so that there is little unnecessary leakage of air. Air movement through closed windows may occur between the window frame and the surrounding wall, through cracks between glass and the framing, through glazing joints, and more particularly through clearance gaps between opening lights and the window frame.

## Air permeability (airtightness)

Leakage of air around window frames, around glass and through glazing joints can be avoided by care in design, construction and maintenance. The necessary clearance gaps around opening lights can be made reasonably airtight by care in design and the use of weatherstripping.

For comfort in living and working conditions in buildings some regular change of air is necessary. The necessary ventilation should be provided through controlled ventilators, through opening lights, or by mechanical ventilation. It is not satisfactory to rely on leakage of air through windows for ventilation as this leakage cannot be

controlled, and it may be excessive for ventilation and conservation of heat or too little for ventilation.

## Air leakage

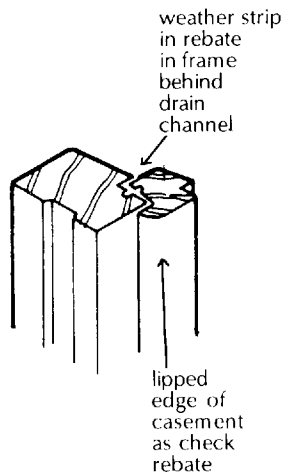


Fig. 15 Weatherstrip and check rebates.

While air leakage through windows will contribute to wastage of heat by an excess of cold air entering, other parts of the building envelope may add considerably to heat loss by leakage of air through construction cracks. An example of this is where a weep hole in the external brick leaf of a cavity wall faces construction gaps around timber joist ends built into the inner skin, so that in high wind measurable volumes of cold air blow into the timber floor. The need for and use of weep holes in cavity walls is questionable, particularly as they will allow cold air to enter the cavity and so reduce the insulating properties of this construction. In many traditionally constructed buildings some one third or more of all air leakage is through construction gaps and cracks. Close attention should therefore be paid to the solid filling or sealing of all potential construction gaps and cracks as well as controlling leakage through windows.

The flow of air through windows is caused by changes in pressure and suction caused by wind that may cause draughts of inward flowing cold air and loss of heat by excessive inflow of cold and outflow of warmed air. It is to control this air movement that systems of check rebates and weatherstripping are used in windows, as illustrated in Fig. 15.

The performance of windows with regard to airtightness is based on predicted internal and external pressure coefficients which depend on the height and plan of the building. These are related to the design wind pressure which is determined from the exposure of the window and basic wind speed from the map in Fig. 14. From these, test pressure classes are established for use in the tests for air permeability and watertightness to set performance grades.

## Watertightness

Penetration of rain through cracks around opening lights, frames or glass occurs when rain is driven on to vertical windows by wind, so that the more the window is exposed to driving rain the greater the likelihood of rain penetration.

Because of the smooth, impermeable surface of glass, driven rain will be driven down, across and up the surface of glass thus making seals around glass and clearance gaps around opening lights vulnerable to rain penetration.

The tests for watertightness of windows are based on predictions similar to those used for air infiltration in determining design wind speed, exposure grades and test pressure classes to set performance standards.

On sites where there is high exposure to wind-driven rain it may be reasonable to adopt a higher performance for watertightness than

that used for strength and stability, to ensure watertightness and to avoid the need for thick mullions, transomes and glass.

To minimise the penetration of driven rain through windows, it is advantageous to:

- (1) Set the face of the window back from the wall face so that the projecting head and jamb will to some extent give protection by dispersing rain.
- (2) Ensure that external horizontal surfaces below openings are as few and as narrow as practicable to avoid water being driven into the gaps.
- (3) Ensure that there are no open gaps around opening lights by the use of lapped and rebated joints and that where there are narrow joints that may act as capillary paths there are capillary grooves.
- (4) Restrict air penetration by means of weatherstripping on the room side of the window so that the pressure inside the joint is the same as that outside; a pressure difference would drive water into the joint.
- (5) Ensure that any water entering the joints is drained to the outside of the window by open drainage channels that run to the outside.

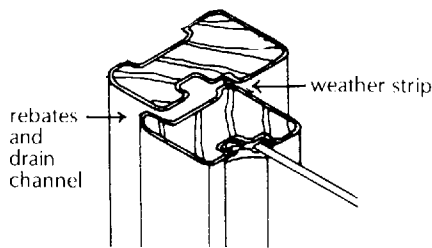


Fig. 16 Drainage channel.

## Durability and freedom from maintenance

### Wood windows

The durability of the traditional material for windows – wood, has been established over centuries. The majority of wood windows are of softwood that suffers moisture movement with change of moisture content and may rot where water enters open joints, if it is not adequately protected by paint or other protective coating. A wood window strongly framed from sound well-seasoned wood protected by a sufficiently elastic paint coating, that is adequately maintained, may have a useful life comparable to that of most buildings. The disadvantage of softwood windows is that they need comparatively frequent maintenance expenditure at intervals of 5 to 7 years. It is the maintenance cost of wood windows that has led, over recent years, to the large market in ‘replacement windows’ of uPVC and aluminium.

### Steel windows

Steel windows have acquired a bad name due to the progressive, corrosive rusting that occurred with the early use of mild steel sections which were not protected with a galvanised zinc coating. Steel windows have been unable to regain favour in competition with uPVC and aluminium windows, and because a galvanised coating



does not give total protection against corrosion, these windows need comparatively frequent painting.

## **Aluminium windows**

On exposure to air, aluminium forms an oxide that generally protects the aluminium below it from further corrosion. The oxide coating that forms on aluminium is coarse textured, dull and silver-grey in colour which readily collects dirt, it not easily cleaned and has an unattractive appearance. For these reasons aluminium is usually coated by anodising, polyester powder, organic or acrylic coatings, to inhibit corrosion and for appearance sake. Anodised finishes may fail after some years, whereas organic powder coating and acrylic coatings survive for many years and require cleaning by washing with water from time to time to maintain appearance. The powder and acrylic coatings are applied in a full range of colours. White is preferred as it does not suffer colour bleaching as do the stronger colours.

## **uPVC windows**

Windows made from PVC sections have been in use for more than 30 years. The material has maintained its original characteristics over this period in various climatic conditions and there is reason to suppose uPVC windows have a useful life similar to that of most buildings. Strongly coloured uPVC will, after some years, bleach due to the effect of ultraviolet light. The colour loss is irregular and unsightly and overpainting of uPVC is not generally successful. The use of white or off-white is recommended. The smooth surface of this material will, after some time, collect a layer of grime that can be easily removed by washing with water. Other than occasional washing these windows need no maintenance.

## **Glass**

A layer of grime will collect on the surface of glass over the course of a month or two, to the extent that it is unsightly and reduces light transmission. To maintain its lustrous, fire-glazed finish, glass needs cleaning at intervals of one to two months by washing with water and polishing dry with a linen scrim cloth.

An extremely thin protective coating of copolymer which can be sprayed over the surface of glass, appreciably reduces the build-up of a dirt film and facilitates cleaning. This sprayed on coating can only be applied in factory conditions to glass cut ready for glazing.

## **Fire safety**

The requirements from Part B of Schedule 1 to the Building Regulations are concerned to:

- Provide adequate means of escape
- Limit internal fire spread (linings)
- Limit internal fire spread (structure)

Limit external fire spread

Provide access and facilities for the fire service

The current advisory document giving practical guidance to meeting the requirements of the Building Regulations is Approved Document B, entitled Fire Safety. It is concerned with the escape of people from buildings after the outbreak of fire rather than the protection of the building and its contents.

## **External fire spread**

The requirement in the Regulations that concerns windows is external fire spread. To limit the spread of fire between buildings, limits to the area of 'unprotected areas' in walls and finishes to roofs, close to boundaries, are imposed by the Building Regulations. The term 'unprotected area' is used to include those parts of external walls that may contribute to the spread of fire between buildings. Windows are unprotected areas, as glass offers negligible resistance to the spread of fire. In Approved Document B rules are set out that give practical guidance to meeting the requirements of the Building Regulations in regard to minimum distances of walls from boundaries and maximum unprotected areas.

## **Resistance to the passage of heat**

A window, which is a component part of a wall or roof, will affect thermal comfort in two ways, firstly by transmission (passage) of heat and secondly through the penetration of radiant heat from the sun, that causes 'solar heat gain'. Glass, which forms the major part of a window, offers poor resistance to the passage of heat and readily allows penetration of solar radiation.

The transfer of heat through a window is a complex of conduction, convection and radiation. Conduction is the direct transmission of heat through a material, convection the transmission of heat in gases by circulation of the gases, and radiation the transfer of heat from one body of radiant energy through space to another.

## **U value**

Because of the variable complex of these modes of transfer it is convenient to adopt a standard average thermal transmittance coefficient (U) as a comparative practical measure of heat loss through materials in steady state conditions. This comparative standard measure of heat transfer, known as the 'U' value, is the heat in Watts that will be transferred through  $1 \text{ m}^2$  of a construction where there is a difference of 1 degree between the temperature of the air on opposite sides  $\text{W/m}^2\text{K}$ . In using this unit of measure of heat transfer, assumptions are made about the moisture content of materials, the rate of heat transfer to surfaces by radiation and convection, the rates of air flow in ventilated spaces, and heat bridge effects.

Glass has low insulation and high transmittance value. The U value

of a single sheet of 6 mm thick glass (single glazing) is  $5.4 \text{ W/m}^2\text{K}$  and that of a double glazed unit with two 6 mm thick sheets of glass spaced 12 mm apart is  $3.0 \text{ W/m}^2\text{K}$ , as compared to that of an insulated cavity wall of  $0.45 \text{ W/m}^2\text{K}$ . Because glass has relatively poor resistance to the passage of heat as compared to that of an insulated wall, it is advantageous to limit the area of glass in buildings for the conservation of energy. This is the assumption in the Building Regulations.

In Approved Document L, to the Building Regulations, three methods are given for determining limitation of heat loss through the building fabric to provide reasonable conservation of fuel and power.

## **Elemental method**

The first method, an Elemental method which applies to dwellings and buildings other than dwellings, is used to select elements of building that will provide satisfactory thermal performance through achieving the Standard U values given for the elements of building. The Elemental method is used as a standard of annual energy use, as a measure against which the annual energy use, determined by the other two methods, is judged.

## **Elemental method dwellings**

The Elemental method used for dwellings (houses and flats) depends on a table of Standard U values applied to the elements of building, roofs, walls, floors and windows. U values are given for an SAP Energy rating of 60 or less and for an SAP Energy rating over 60.

## **Standard assessment procedure (SAP)**

The SAP rating, which is used for dwellings only, is calculated by the completion of a worksheet of four pages with reference to the accompanying 14 tables. The sequential completion of up to 99 entries on the worksheet by reference to the 14 tables is laborious. The end result is an SAP rating on a scale of 0 to 100; the higher the performance number, the better the thermal performance of the building in limiting the use of energy and power. SAP ratings of 60 or less are assumed to provide thermal performance below that set by the Regulations.

## **Windows**

The Standard U values for dwellings are set out in Table 4. The Standard U value for windows in a building with an SAP rating of over 60 is  $3.3 \text{ W/m}^2\text{K}$  where the area of windows does not exceed 22.5% of the total floor area.

The U value of a window depends on the type of glazing and the materials of the window framing. As single glazing does not provide a sufficiently low U value, some form of double glazing is necessary. The overall U value of a window varies to some extent on the materials used in window framing, as wood and uPVC frames provide better insulation against heat transfer than metal. The overall U value

**Table 4** Standard U values ( $\text{W/m}^2\text{K}$ ) for dwellings.

| Element                          | For SAP Energy Ratings of: |                     |
|----------------------------------|----------------------------|---------------------|
|                                  | 60 or less<br>(a)          | over 60<br>(b)      |
| Roofs <sup>(1)</sup>             | 0.2                        | 0.25 <sup>(2)</sup> |
| Exposed walls                    | 0.45                       | 0.45                |
| Exposed floors and ground floors | 0.35                       | 0.45                |
| Semi-exposed walls and floors    | 0.6                        | 0.6                 |
| Windows, doors and rooflights    | 3.0                        | 3.3                 |

**Notes**

1. Any part of a roof having a pitch of  $70^\circ$  or more may have the same U-value as a wall.
2. For a flat roof or the sloping parts of a room-in-the-roof construction it will be acceptable if a U value of  $0.35 \text{ W/m}^2\text{K}$  is achieved.

of a wood or uPVC window frame with a sealed double glazed unit with a 6 mm air gap is  $3.3 \text{ W/m}^2\text{K}$ , whereas one with a metal frame and similar double glazing is  $4.2 \text{ W/m}^2\text{K}$ .

**Modification of basic allowance**

The basic allowance for the area of windows, 22.5% of the total floor area, may be modified where there is compensating improvement in the average U value of windows. An example of this is where a wood frame window is glazed with a double glazed unit with a 12 mm sealed air gap which is filled with low E (Emissivity) Argon gas. Here the U value of the window and frame is taken as  $2.2 \text{ W/m}^2\text{K}$  and the modified allowance for the maximum area of the window is 36.5% of the total floor area.

**Elemental method, buildings other than dwellings**

The Elemental method of determining the required limitation of heat loss for buildings other than dwellings is similar to that for dwellings except that the SAP rating is not used. Standard U values are set out in Table 5.

The basic allowance of area for windows is expressed as a percentage of exposed wall area. These percentages vary from 15% for industrial and storage buildings to 40% for shops and offices. Similarly there is a modification of the basic allowance for the area of windows where the average U value is less than that allowed in Standard U values.

The two other methods of showing compliance with requirements for limitation of heat loss for dwellings are a Target U value method and an Energy rating method and those for buildings other than dwellings are a Calculation method and an Energy Use method.

The three methods of showing compliance with requirements for limitation of energy use for dwellings and for buildings other than

**Table 5** Standard U values (W/m<sup>2</sup>K) for buildings other than dwellings.

| Element                                 | U-value             |
|-----------------------------------------|---------------------|
| Roofs <sup>(1)</sup>                    | 0.25 <sup>(2)</sup> |
| Exposed walls                           | 0.45                |
| Exposed floors and ground floors        | 0.45                |
| Semi-exposed walls and floors           | 0.6                 |
| Windows, personnel doors and rooflights | 3.3                 |
| Vehicle access and similar large doors  | 0.7                 |

**Notes**

1. Any part of a roof having a pitch of 70° or more may have the same U value as a wall.
2. For a flat roof or insulated sloping roof with no loft space it will be acceptable if a U-value of 0.35 W/m<sup>2</sup>K is achieved for residential buildings or 0.45 W/m<sup>2</sup>K for other buildings.

dwellings and the SAP rating calculation are described in more detail in Volume 1.

## Solar heat gain

The term 'radiation' describes the transfer of heat from one body through space to another. When the radiant energy from the sun passing through a window reaches, for example, a floor, part of the radiant energy is reflected and part absorbed and converted to heat. The radiant energy reflected from the floor will in part be absorbed by a wall and converted into heat and partly reflected. The heat absorbed by the floor and wall will in turn radiate energy that will be absorbed and converted to heat.

This process of radiation, reflection, absorption, conversion to heat and radiation will produce rapidly diminishing generation of heat. The heat generated by radiation will be dissipated by conduction in solid materials such as walls, and by convection in air.

The wavelength of radiant energy depends on the temperature of the radiating body: the higher the temperature the shorter the wavelength. Part of the radiation of energy from the extremely high temperature of the sun is short wave which will pass through clear glass with little absorption, whereas the comparatively low temperature and long wavelength of an electric fire and a floor or wall will mostly be absorbed by glass.

Where the balance of gain of heat from radiation is greater than that dissipated by conduction and convection, there will be a gradual build-up of heat that can cause discomfort in rooms due to solar heat gain.

Plainly the degree of solar heat gain is affected by the size and orientation of windows. Large windows facing south in the northern hemisphere will be more affected than those facing east or west. The

time of year will also have some effect between the more intense summer radiation which will not penetrate deeply into rooms at midday to the less intense but more deeply penetrating radiation of spring and autumn.

In the temperate climate of northern Europe discomfort from solar heat has not, until recently, been a concern. Sunlight is welcome as a relief from preponderant, dull overcast days. In middle and southern Europe systems of shutters and blinds are used to provide shade from the more intense radiation of summer sun.

Discomfort from solar heat gain has mainly been a consequence of the fashion to use large areas of glass as a sealed walling material for offices and other non-domestic buildings, where the build-up of heat can make working conditions uncomfortable. The transmission of solar radiation can be effectively reduced by the use of body tinted, surface modified or surface coated glass to control solar heat gain.

## Resistance to the passage of sound

**Table 6** Sound pressure levels for some typical sounds.

| Sound                              | Sound pressure level (dB) |
|------------------------------------|---------------------------|
| Threshold of hearing               | 0                         |
| Leaves rustling in the wind        | 10                        |
| Whisper or ticking of a watch      | 30                        |
| Inside average house, quiet street | 50                        |
| A large shop or busy street        | 70                        |
| An underground train               | 90                        |
| A pop group at 1.25 m              | 110                       |
| Threshold of pain                  | 120                       |
| A jet engine at 30 m               | 130                       |

Sound is the sensation produced through the ear by vibrations caused by air pressure changes superimposed on the comparatively steady atmospheric pressure. The rate or frequency of the air pressure changes determines the pitch as high pitch to low pitch sounds. The audible frequencies of sound are from about 20 Hz to 15 000 or 20 000 Hz, the abbreviation Hz representing the unit Hertz where one Hertz is numerically equal to one cycle per second. The sound pressure required for audibility is generally greater at very low frequencies than at high frequencies.

Because of the variation in the measured sound pressure and that perceived by the ear over the range of audible frequencies, a simple linear scale will not suffice for the measurement of sound. The measurement that is used is based on a logarithmic scale that is adjusted to correspond to the ear's response to sound pressure.

The unit of measurement used for ascribing values to sound levels is the decibel (dB). Table 6 gives sound pressure levels in decibels for some typical sounds. Because the sensation of sounds at different frequencies, although having the same pressure or energy, generally appears to have different loudness, a sound of 100 dB is not twice as loud as one of 50 dB, it is very much louder. The scale of measurement used to correlate to the subjective judgement of loudness, which is particularly suitable for traffic noise, is the A weighting with levels of sound stated in dB (A) units.

The word loud is commonly taken to indicate the degree of strongly or clearly audible sound, and the word noise as distracting sound.

To provide a measure of generally accepted tolerable levels of audible sound, which will not distract attention or be grossly intrusive, tolerance noise levels are set out in Table 7.

**Table 7** Tolerance noise levels.

| Location                                                              | dB(A) |
|-----------------------------------------------------------------------|-------|
| Large rooms for speech such as lecture theatre, conference rooms etc. | 30    |
| Bedrooms in urban areas                                               | 35    |
| Living rooms in country areas                                         | 40    |
| Living rooms in suburban areas                                        | 45    |
| Living rooms in busy urban areas                                      | 50    |
| School classrooms                                                     | 45    |
| Private offices                                                       | 45–50 |
| General offices                                                       | 55–60 |

## Airborne sound

## Impact sound

Sound is produced when a body vibrates, causes pressure changes in the air around it and these pressure changes are translated through the ear into the sensation of sound. Sound is transmitted to the ear directly by vibrations in air pressure – airborne sound, or partly by vibrations through a solid body that in turn causes vibrations of air that are heard as sound – impact sound. The distinction between airborne and impact sound is made to differentiate the paths along which sound travels, so that construction may be designed to interrupt the sound path and so reduce sound levels. Airborne sound is, for example, noise transmitted by air from traffic through an open window into a room and impact sound from a door slamming shut that causes vibrations in a rigid structure that may be heard some distance from the source.

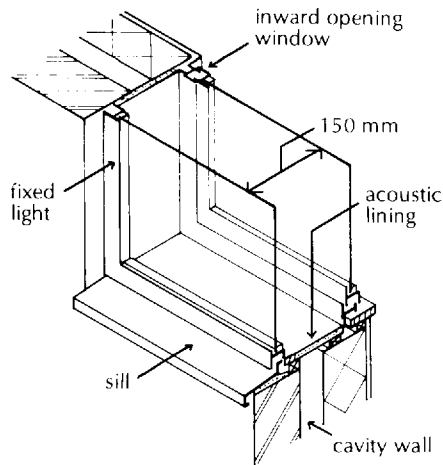
The sensation of sound is affected by the general background level of noise to the extent that loud noise may be inaudible inside a busy machine shop, while comparatively low levels of sound may be disturbing inside a quiet reading room.

For the majority of people, who live and work in built-up areas, the principal sources of noise are external traffic, airborne sound, and internal noise from neighbouring radios, televisions and impact of doors and footsteps on hard surfaces, impact and airborne sounds.

Windows and doors are a prime source for the entry of airborne sound both through glass, which affords little insulation against sound, and by clearance gaps around opening parts of windows and doors. Appreciable reduction of intrusive airborne sound can be effected by weatherstripping around the opening parts of windows and doors.

The transmission of sound through materials depends mainly on their mass; the more dense and heavier the material the more effective it is in reducing sound. The thin material of a single sheet of glass provides poor insulation against airborne sound.

A small increase in insulation or sound reduction of glass can be



**Fig. 17** Double window for sound insulation.

effected by the use of thicker glass, where an average reduction of 5dB is obtained by doubling the thickness of glass. There is no appreciable sound reduction by using the sealed double glazed units that are effective in heat insulation, as the small cavity is of no advantage, so that sealed double glazing is no more effective than the combined thickness of the two sheets of glass. For appreciable reduction in sound transmission double windows are used where two separate sheets of glass are spaced from 100 to 300 mm apart. An average reduction of 39 dB with 100 mm space and 43 dB with 200 mm space can be obtained with 4 mm glass. This width of air space is more than the usual window section can accommodate and it is necessary to use some form of double window.

The double window illustrated in Fig. 17 comprises two windows, a fixed outer and an inward opening inner window with the glass spaced 50 mm apart. Acoustic lining to the sill, jambs and head between the windows absorbs sound. The hinged inner sash facilitates cleaning glass.

## Security

Windows and doors are the principal route for illegal entry to buildings. Of the recorded cases of illegal entry, burglary, about 30% involve entry through unlocked doors and windows. Of the remaining 70% some 20% involve breaking glass to gain entry by opening catches, and the remaining 80% by forcing frames or locks. As speed is of the essence in successful burglary, well-lit and exposed windows and doors are less likely to be attacked than out-of-sight rear windows and doors.

Locks, bolts and catches to windows and doors are forced open by inserting a tool in the clearance gap between the opening parts of windows and doors and the frame so that the lock, bolt or catch is disengaged from the frame. Plainly flimsy frame, sash and door material can more readily be prised apart than solid material, and lightweight single locks that shoot shut a small distance into frames are more readily prised open than heavy locks that shoot shut some distance into frames. Similarly flimsy or ill-fitted hinges can be prised loose from frames. Window and door frames insecurely fixed can be prised away from the surrounding wall.

Of the materials used for windows, uPVC can more easily be deformed than more rigid wood, steel or aluminium sections, to prise locks open particularly where lock and bolt fittings are not secured to the steel or aluminium reinforcement in uPVC sections.

Security against locks, bolts, catches and hinges being forced open depends on reasonably rigid frame and opening window sections, and strong lock, bolt, catch and hinge material being securely fixed. Plainly where more than one substantial lock or bolt is used with sound frame and window material the better the security.



Even though glass is comparatively easy to smash or cut, breaking glass is the least favoured method of illegal entry, principally because the distinctive sound of breaking glass may alert householders. Small panes of glass in putty glazing are more difficult to break than large panes and jagged edges of glass left in the putty are themselves a hazard to entry. The majority of uPVC and aluminium windows are glazed with beads, often fixed externally. It is fairly easy to remove these beads that are either screwed in place or are of the 'pop-in' type where the beads fit to projections in the sash or frame and are held by friction. Where there is ease of access, beads should either be of the shuffle type which require considerable force to be removed from outside or they should be fixed internally. Once beads have been removed it is usually easy to take out the glass. To make it more difficult the glass can be secured with double-sided tape or glass retaining clips. The purpose of breaking glass is to open catches to windows from outside for ease of entry. It is only after the glass has been broken that the burglar may find that the catches are locked shut.

Wired glass, which can easily be broken, will make it more difficult to make a clear opening because much of the broken glass will remain attached to the wire and so impede access. Toughened glass, which is considerably more difficult to break than ordinary glass, may deter all but the most determined burglar. Laminated glass is the best protection against burglary as the glass, which is not easily broken, will not shatter but break to small fragments which have to be removed for access. Double glazing is only more secure than single to the extent that there are two sheets of glass to break.

All security measures involve extra cost in better quality frames, sashes, locks, bolts, hinges and glass. It is wise, therefore, to employ security measures on those windows and doors most vulnerable to attack. From recorded cases it is clear that 62% of burglaries occur at the rear of buildings where there is ease of access to the 14–17 year old age group of preponderant opportunist burglars, and where access is out of sight.

A disadvantage of security against illegal entry from outside is that means of escape to the outside is made that much more difficult in case of need. The balance of advantage is to provide reasonable security to those windows and doors most vulnerable to burglary, with some allowance for ease of escape where burglary is least likely.

The practical guidance in Approved Document N to the Building Regulations recommends the use of safety glass to windows and glazed panels up to a level of 800 mm above finished floor level. It is at this low level above the floor that children are particularly vulnerable.

## MATERIALS USED FOR WINDOWS

### Wood windows

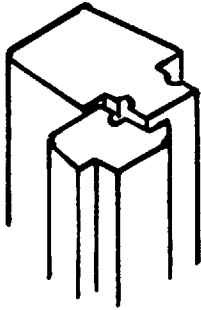


Fig. 18 Wood window sections.

The material traditionally used for windows is wood, which is easy to work by hand or machine and can readily be shaped for rebates, drips, grooves and mouldings, as illustrated in Fig. 18. It has a favourable strength to weight ratio, and thermal properties (see Volume 1, Timber) such that the window members do not act as a thermal bridge to heat transfer.

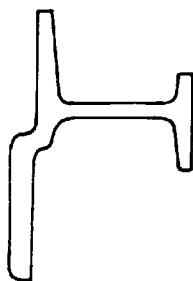
The disadvantages of wood are the considerable moisture movement that occurs across the grain with moderate moisture changes, and liability to rot. The dimensional changes can cause joints to open to admit water, which increases the moisture content that can lead to rot. It is of prime importance, therefore, that the moisture content of timber at the time of assembly be 17% or less, that the timber be treated with a preservative, and that the assembled window has a protective coating such as paint which is regularly maintained. It is necessary to maintain a sound paint film over the end grain of wood as it is more vulnerable than the long grain, in particular the end grain on the end of the stiles at the top of casements which are exposed to rain.

The majority of wood frames are cut from softwood timbers such as Baltic redwood (red and yellow deal), red pine and fir. Ideally sapwood should be excluded from timber for joinery as it is more liable to decay than heartwood (see Volume 1). In practice it is not economically possible to exclude sapwood. There is, therefore, good reason for preservative treatment of softwood to minimise the likelihood of rot. Preservative-treated softwood should none the less be protected with paint.

It is the need for regular and costly painting that is the particular disadvantage of softwood windows.

### Steel windows

Following the industrial revolution it became practical and economic to produce mild steel sections which were developed by Crittall's in the early 1880s as hot rolled, steel section window frames and sashes. The comparatively small sections used for these windows were adopted more for aesthetic than practical reasons. The slim section steel window became the modern fashion of the late nineteenth and early twentieth centuries. These early steel windows were protected by paint which was not successful in preventing progressive, corrosive rusting and the steel window lost favour until the 1940s when steel windows, protected with hot-dip galvanising, were introduced. The galvanised zinc coating greatly reduced the onset of rusting. The limited sections that are practical with the hot rolled method of forming steel limited the types of window that could be made, made it difficult to accommodate double glazing and effective draught seals and contributed to the loss of favour of these windows.

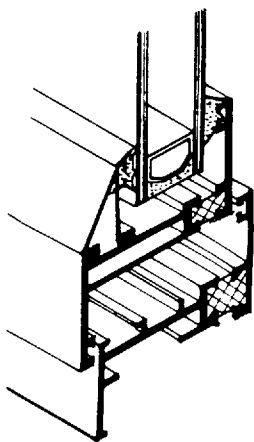


**Fig. 19** Steel window section.

The advantage of steel for windows is the slender sections for both frame and opening lights that are possible due to the inherent strength and rigidity of the material. Figure 19 is an illustration of a steel window section. The disadvantages are high thermal conductivity that makes the window framing act as a cold bridge to the transfer of heat, the very necessary regular painting required to protect the steel from rusting, and the fact that narrow sections do not readily accommodate double glazing.

The majority of steel sections for windows are made from hot-rolled steel bars which is an expensive process from which only a limited range of sections can be produced economically. In Europe, pressed or rolled sheet steel sections and cold deformed tube sections have been used to produce a greater variety of sections for window manufacture. Rolled steel section windows are much less used today than they were.

## Aluminium windows



**Fig. 20** Aluminium window section.

Aluminium windows were first used in this country in the early 1930s and have been in use since then. These windows are made from aluminium alloy to BS 4873:1986, that is extruded in channel and box sections with flanges and grooves for rebates and weatherstripping. These thin-walled channel and box sections give the material adequate strength and stiffness for use as window sections, as illustrated in Fig. 20. The material can be readily welded and has good resistance to corrosion.

The aluminium alloy used is resistant to corrosion that might cause loss of strength, yet the surface of the material will fairly rapidly lose lustre owing to white corrosion products and some pitting caused particularly in marine and industrially polluted atmospheres. This corrosive effect may be inhibited by anodising or liquid organic or powder coating. To maintain the initial lustre of the surface of these windows it is necessary to wash them at regular intervals.

Aluminium windows are generally more expensive than comparable wood or steel windows. The advantages of aluminium windows are the variety of sections available for the production of a wide range of window types, and the freedom from destructive corrosion. The disadvantage is the high thermal conductivity of the material which acts as a cold bridge to heat transfer. To prevent aluminium section windows acting as a thermal bridge, they are constructed as two sections mechanically linked by a plastic bridge that acts as a thermal break. As an alternative the inner face of the aluminium is covered with a plastic, clip-on facing.

## Stainless steel windows

This expensive corrosion-resistant steel product is made from an alloy of steel with chromium, nickel and molybdenum in the proportions of 18, 10 and 3 as a percentage of the whole to steel. This costly material

is used in windows as a thin surface coating to other materials such as wood and aluminium for its appearance and freedom from corrosion. To keep its initial lustre the stainless steel finish requires regular washing.

### **Bronze windows**

In the late nineteenth and early twentieth centuries bronze windows were used for large monumental scale buildings such as banks and civic buildings. These very expensive windows of strong, slender section metal, which does not rust and maintains its attractive colour, were the fashion for many large buildings at the time.

Manganese brass is the material commonly used for bronze windows. The material is rolled or extruded to form window sections. This very expensive material is less used today. Its advantages are freedom from corrosion, high strength to weight ratio, and the attractive colour and texture of the material.

### **Plastics, uPVC windows**

The word plastics is used in a general sense to embrace a wide range of semi-synthetic and synthetic materials that soften and become plastic at comparatively low temperatures so that they can be shaped by extrusion or pressure moulding or both.

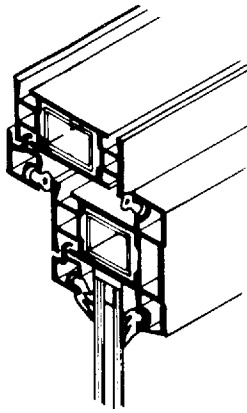
In the middle of the nineteenth century semi-synthetic plastics such as vulcanite or ebonite were produced from rubber and processed by the addition of sulphur to make tyres and imitation jewellery. Later in the century casein, which is made from milk curds treated with formaldehyde, was used to make ornamental articles. Celluloid, made from nitric acid, sulphuric acid and cellulose, was formed by heating, moulding and carving in the production of a wide range of decorative objects such as hand mirrors, combs and knife handles as a substitute for ivory and also for photographic film.

In the early years of the twentieth century the first synthetic plastics were produced in the form of a synthetic resin, Bakelite. Subsequent developments led to the synthesis and use of a range of synthetic plastics called polymers, which is the name of the range of plastics in common use today for building and a wide range of domestic products.

The polymer, polyvinyl-chloride (PVC) was first extensively used in forming window sections in Germany during the middle of the twentieth century. The polymer in the form of unplasticised (rigid) polyvinyl-chloride (uPVC) is softened by heating, extruded through a die and pressure formed to produce hollow box sections for window frames and sashes.

### **High impact modified uPVC**

More recently, modifiers such as acrylic have been added to the constituent materials of uPVC to improve the impact resistance of the material which is, by itself, fairly readily subject to damage by slight



**Fig. 21** uPVC window section.

knocks or abrasions. The addition of modifiers affects the speed at which the heated material is extruded, otherwise the finished product is liable to surface ripples and variations in thickness, if the speed of extrusion is too rapid.

The particular advantage of this material is that it is maintenance free and will maintain its smooth textured surface for the useful life of the material with occasional washing to remove grime. As the material is formed by extrusion it is practical to form a variety of rebates and grooves to accommodate draught seals, as illustrated in Fig. 21. The basic colour of the material is off-white which is colourfast on exposure to ultraviolet light for the useful life of the material. A range of coloured plastics can be produced either with the colour integral to the whole of the material or as a surface finish. Dark colours are more susceptible to bleaching and loss of colour in ultraviolet light from sun than light ones.

Because uPVC has less strength and rigidity than metal sections, it is formed in comparatively bulky, hollow box sections that are not well suited for use in small windows such as casements. The comparatively large coefficient of expansion and contraction of the material with the change of temperature and its poor rigidity require the use of reinforcing metal sections fitted into the hollow core of the sections to strengthen it and to an extent restrain expansion and contraction. The uPVC sections are screwed to the galvanised steel or aluminium reinforcement to fix the reinforcement in position, restrain deformation due to temperature movement and serve as secure fixing for hardware such as hinges, stays and bolts.

Some manufacturers use reinforcement only for frame sections over 1500 mm in length and casement or sash sections over 900 mm in length. For the advantage of a secure fixing for hardware and fixing bolts it is wise to use reinforcement for all uPVC sections.

uPVC windows are now extensively used both for new buildings and largely as 'replacement windows'.

## WINDOW TYPES

### Fixed lights

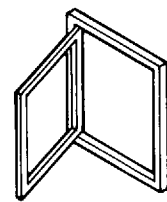
The term fixed light or dead light is used to describe the whole or part of a window in which glass is fixed so that no part of the glazing can be opened. Typically fixed lights are one sheet of glass, several sheets of glass in glazing bars, or lead or copper lights glazed (fixed) directly to the window frame.

### Opening light

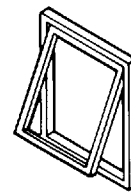
An opening light is the whole or part of a window that can be opened by being hinged or pivoted to the frame or which can slide open inside the frame.

Windows with opening lights may be classified according to the manner in which the opening lights are arranged to open inside the frame, as illustrated in Fig. 22.

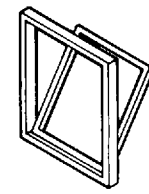
|                  |                                                                                       |
|------------------|---------------------------------------------------------------------------------------|
| Hinged           | Side hung<br>Top hung<br>Bottom hung                                                  |
| Pivoted          | Horizontally pivoted<br>Vertically pivoted                                            |
| Sliding          | Vertically sliding<br>Horizontally sliding                                            |
| Composite action | Side hung projected<br>Top hung projected<br>Bottom hung projected<br>Sliding folding |



side hung casement

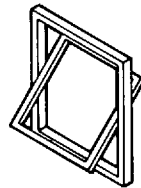


top hung sash



bottom hung sash

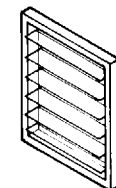
hinged



horizontally pivoted

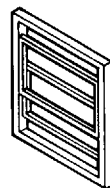


vertically pivoted

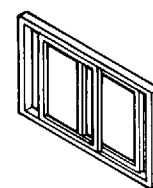


louvre

pivoted

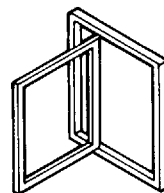


vertically sliding

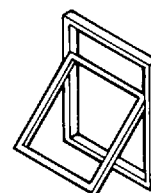


horizontally sliding

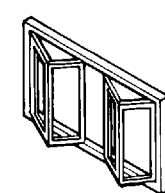
sliding



projected side hung



projected top hung



sliding folding

composite

Fig. 22 Types of opening light.

## Hinged opening lights

The traditional wood casement or cottage window comprised one or more comparatively small opening casements, generally with glazing bars to suit the comparatively small panes of glass that were available before the production of drawn sheet and float glass. These small windows provided sufficient daylight for indoor activities and the

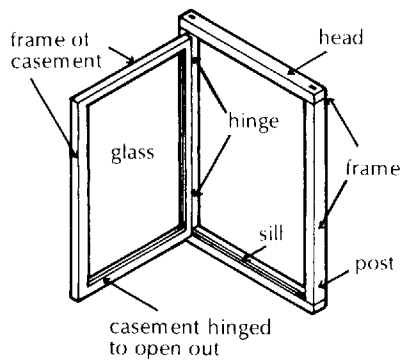


Fig. 23 Side hung casement window.

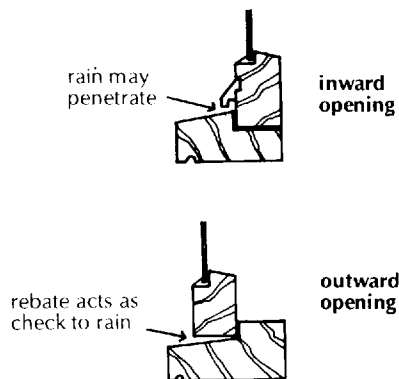


Fig. 24

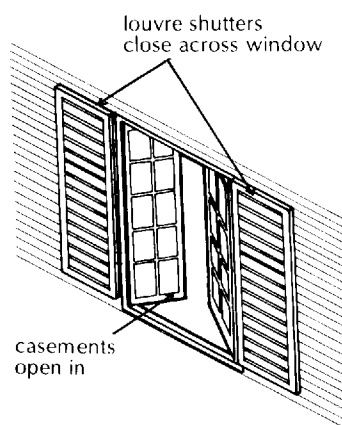


Fig. 25 French casement.

least heat loss through glass and draughts of cold air from cracks around casements, for the indoor comfort of the majority of the population who, before the industrial revolution, spent the major part of their lives in the open.

A casement consists of a square or rectangular window frame of wood with the opening light or casement hinged at one side to the frame to open in or out. The side-hung opening part of the window is termed the casement and it consists of glass surrounded and supported by a wooden frame as shown in Fig. 23, which is an illustration of a simple one-light casement opening out.

Because a casement is hinged on one side, its other side tends to sink due to the weight of the casement when it is open. If any appreciable sinking occurs the casement will bind in the window frame and in time may be impossible to open. Obviously, the wider a casement the greater its weight and the more likely it is to sink. It would be possible to increase the size of the members of the frame of a wide casement to strengthen it against sinking. It is not considered satisfactory to do this as the larger frame members would decrease the area of glass.

It is generally considered unwise to construct casements wider than say 600 mm. A casement window wider than 600 mm will consist of two or more casements or a casement and a dead light.

The traditional English casement is hinged to open out. The advantage of this is that an outward opening casement can more readily be made to exclude wind and rain than one opening inwards.

With an outward opening window the casement is forced into the outward facing rebate of the window frame by wind pressure, whereas with an inward opening casement the casement is forced away from the inward facing rebate of the window frame, as illustrated in Fig. 24, and so acts as a less effective seal against wind and rain.

Another advantage of the outward facing casement is that it will not obstruct curtains when they are drawn together.

In Europe the traditional casement is hung to open in, generally in the form of a pair of casements that often extend to the floor in the form of a pair of fully glazed doors, termed French casements, that may either serve as windows or give access to a balcony and serve as doors and windows.

The French casements, illustrated in Fig. 25, have been adopted for the warmer southern European countries where the casements may be opened inward and externally fixed, louvred wood shutters closed over the opening to exclude sun and allow some ventilation through the louvres.

A casement window may be framed with a pair of casements hinged

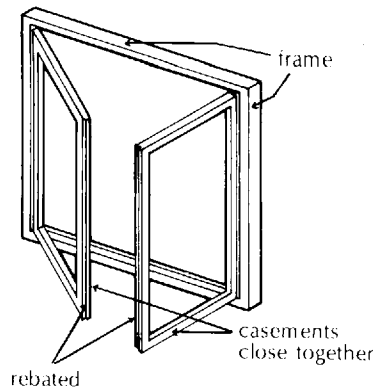


Fig. 26 Pair of casements.

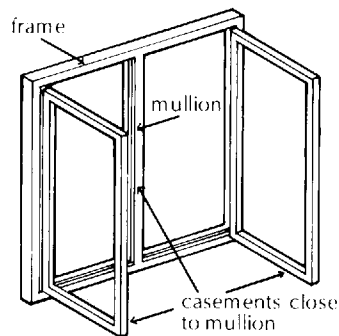


Fig. 27 Casements and mullion.

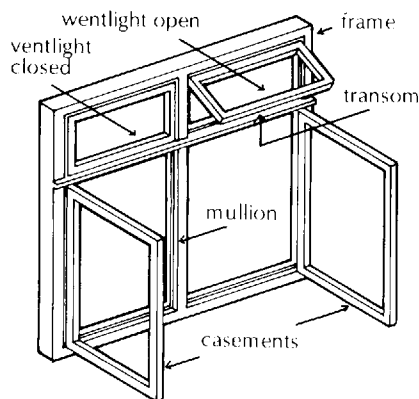


Fig. 28 Casements and ventlights.

to close together inside the frame as illustrated in Fig. 26. The vertical meeting stiles of the two casements are rebated to exclude wind and rain when the casements are closed. The advantage of this arrangement is that there is the least width of framing members to obstruct the glazed area.

The disadvantages of this arrangement is that the casements will need top and bottom bolts, in addition to a central catch, to close them firmly into the window frame to exclude wind and rain. Any slight loss of shape of either one or both of the casements, due to sinking, may cause them to bind inside the frame, make them difficult to open or close and result in further distortion of shape. Such poorly fitting casements will be ineffective in excluding wind and rain.

A sounder method of framing a two light casement window is by the use of a central window frame member so that each casement is hinged to open and close into a separate framed opening as illustrated in Fig. 27. The frame member that separates the casement is termed a mullion. The additional frame member, the mullion, does to an extent reduce the area available for glazing.

The advantage of this arrangement is that distortion of one casement will not affect the closing of the other and that each casement can be adequately secured with a latch to exclude wind and rain.

It may not be possible to open a casement just sufficient for ventilation without allowing gusts of wind to enter. It has been common to provide small opening lights, called ventlights, which are usually hinged at the top to open out to provide more closely controlled ventilation.

So that the ventlights can be opened independently of the casements, the window frame is made with a horizontal member, called a transom to which casements and ventlights close as illustrated in Fig. 28. Casements with ventlights are usually designed so that the transom is above the average eye level of people using the room, for obvious reasons.

The disadvantages of a casement window are that the casements, ventlights, mullions and transom reduce the possible unobstructed area of glass and therefore daylight through a window and that the many clearance gaps around opening casements and ventlights emphasise the problem of making the window weathertight.

An outward-opening casement may be difficult to clean from inside and is not suited to tall buildings where there is no outside access. The many corners of glass to the comparatively small casements and ventlights make window cleaning laborious such that corners of glass are not cleaned and become grimy, further restricting the area of clear glass available for daylight penetration.

Ventlights that are left open when a building is unoccupied provide



a means of entry by putting an arm through the ventlight to open the catch of casements below.

## Dead lights

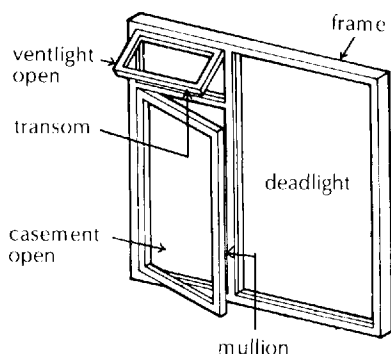


Fig. 29 Casement window with deadlight.

Of recent years it has been fashionable to use windows with as large an unobstructed area of glass as possible and the casement window, with its mullions and transom and comparatively small casements, has lost favour. The manufacturers of standard casement windows now make a range of windows which provide a large dead light by itself, or a dead light with a casement alongside it and a ventlight above, as illustrated in Fig. 29.

This type of window combines the advantage of a large area of glazing for maximum daylight with the facility for ventilation from a casement or ventlight. That part of a window which cannot be opened is termed a dead light or fixed light. The advantage of a dead light is that there is no limitation in width as it does not open and there are no clearance gaps to admit wind and rain.

Rolled steel section windows, which were generally made as casements with ventlights and deadlights in much the same form as wood casements, had the advantage of maximum area of glazing due to the small section of the frame and casement framing members.

Aluminium was initially used as a substitute for rolled steel in similar sections for use in casement windows, the small section aluminium having the advantage that it did not progressively corrode.

Because of their considerable bulk, hollow uPVC window sections are not best suited for casement windows.

## Top and bottom hung windows

These opening lights are principally used for ventilation, the ventilation being controlled by the degree to which the light is opened. Top hung lights open out and bottom hung open in so that the slope of the sash and its glass directs rain outside the building. Usual practice is to position top hung lights at high level, as in the casement window, to encourage warmed air from inside to escape at the sides of the open sash and cold replacement air to enter below the sash as illustrated in Fig. 11. Top hung outward-opening lights are also fixed at high level so that their projection outside is at high level. Bottom hung opening-in lights are generally fixed at low level so that cold air can enter above the open light and some warmed air from inside can escape at the sides of the sash. Bottom hung opening-in lights are sometimes described as hoppers.

Top hung and bottom hung lights are often used in schools, places of assembly and factories, either opened by hand or by winding gear to control circulation of air between inside and outside. Because they are top or bottom hung these lights must have a positive opening and stay mechanism, otherwise they bang shut or fully open and would be subject to wind pressure. There is therefore a limit to their opening.

Being top or bottom hung the opening lights are not so subject to distortion due to their own weight as is the side hung casement, and comparatively large lights with small section frames are practical. A modification of these lights in the form of projected top and bottom hung lights has gained favour recently where the lights have a composite opening action of both sliding and pivoting to open. The disadvantage of these lights is that they may be left open and therefore be a security risk, and the bottom hung light may obstruct curtains.

These lights are made in the same way as side hung casements in wood, metal and plastic and the details of the framing of the lights and the window frame are the same as for side hung casements.

While the bottom hung lights may be cleaned both sides from the inside the top hung lights cannot.

### Pivoted opening lights

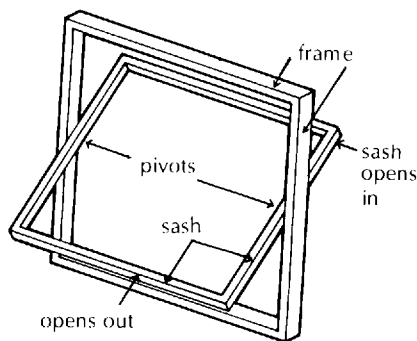


Fig. 30 Horizontally pivoted sash.

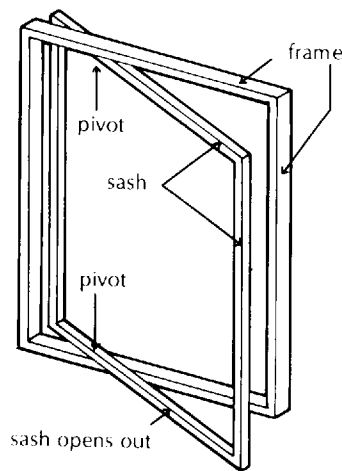


Fig. 31 Vertically pivoted sash.

With the introduction of continuously drawn, clear sheet glass in the middle of the nineteenth century, it became possible to use large single sheets of glass in windows. This facility was at first used to dispense with the many glazing bars previously necessary in casement and vertically sliding windows.

With the availability and demand for the comfort of central or space heating from the middle of the twentieth century, came the demand for larger unobstructed areas of glass. The width of a casement is limited by the strength of the framing in supporting its weight. The advantage of a pivoted opening light is that the weight of the frame and glass is balanced over the pivots that are fixed centrally up the height or over the width of the window, so that framing sections can be the same as those for a casement half the width.

The sashes may be either horizontally or vertically pivoted to open. Horizontally-pivoted sashes are usually pivoted at the centre of the height of the window, as illustrated in Fig. 30, to balance the weight of the sash over the pivots, and vertically-pivoted to open in by one third of their width to provide least obstruction inside as illustrated in Fig. 31. Because the weight of the sash is balanced over the pivots a large sash with small section framing is possible and cleaning the glass on both sides of the window is possible from inside the building. As part of pivoted sashes opens in, it obstructs the movement of curtains. Close control of ventilation with these windows is not possible as they have to open both top and bottom or both sides and they may act like a sail and catch and direct gusts of wind into the building.

Because of the pivot action of these windows the rebate between the sash and the frame has to be reversed around the pivot from inward opening to outward opening and a clearance for the opening action and the pivot has to be provided. This makes it difficult to ensure a weathertight seal around the pivot where the rebate and any weather-

stripping has to be discontinued if the sash is to open. For this reason pivoted sashes are not recommended in positions of severe exposure.

An advantage of pivoted windows is that the glass both inside and outside can be cleaned from inside the building. This advantage may be a cause of danger, particularly in tall buildings, where there are no safety stays to horizontally pivoted sashes. Where someone is cleaning glass from within and the sash is free to pivot and the person cleaning leans too far out to clean the lower edges of glass, he or she may, by accident, fall out of the window. For security, positive stays must be provided to prevent such occurrences.

## Sliding windows

### Vertically sliding sash window

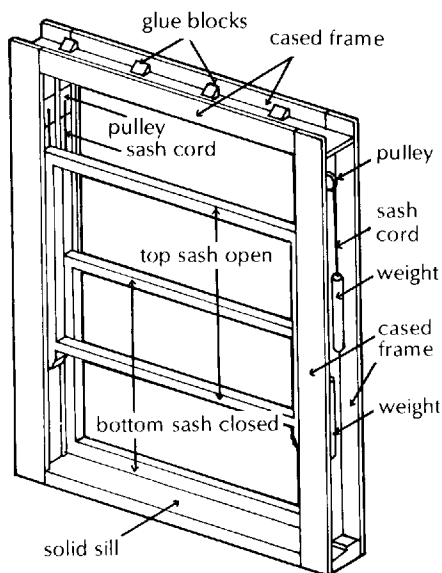


Fig. 32 Vertically sliding sash window.

The word casement is properly used to describe the framing material and glass of a side hung window. The frame material for other opening lights is termed a sash in the same sense that a sash in clothing is used to surround and support.

During the seventeenth century the large casement window with two long, inward-opening sashes, generally extending down to the floor, was developed in France. This French casement or French window was accepted and has remained a principal form of window on the continent of Europe.

At the same time the vertically sliding window, commonly known as a 'double hung sash window', was developed in England and became the common, singularly English window for all but small domestic or cottage windows. The earlier forms of this window operated by supporting the vertically sliding sashes in position by pegs fitted to holes in the side of the frame or by spring cams. The later method of hanging the sliding sashes was by means of ropes or chains over pulleys in the frame, connected to counter weights concealed inside the box frame of the window, as illustrated in Fig. 32.

The advantage of the vertically sliding sash is that as the weight of the sashes is hung vertically on ropes or chains, the sashes do not tend to distort and in consequence large sashes can be framed from small sections and large unobstructed areas of glass are possible. By setting the bulky box frame of these windows behind a rebate in the surrounding wall, the external appearance of the window is of a large area of glass framed in slim members.

Because of the sliding action, the sashes neither project into or out of the building and close control of ventilation is possible between a lower limit of a slight raising of a sash to allow some ventilation between the meeting rails, to an upper limit of opening nearly half the window area. The sliding action facilitates the use of draught seals between sashes and frame.

The disadvantage of this window is that it is not easy to clean glass on both sides from inside the building. This difficulty has been

overcome in recent window design in which it is possible to swing the sashes inwards for cleaning.

In time the traditional sash cords will fray and break and it is comparatively laborious to fit new ones. Sashes suspended in spring balances avoid this.

### Horizontally sliding sash window

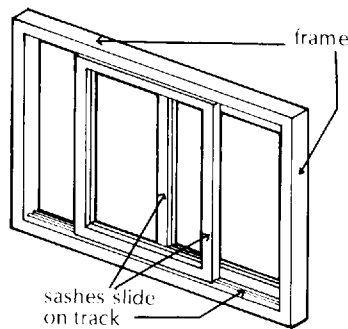


Fig. 33 Horizontally sliding sash window.

A traditional form of horizontally sliding wood window is that known as a Yorkshire light or cottage window, illustrated in Fig. 33. This crude form of small window comprised two timber-framed sashes that slid horizontally on wood runners inside a solid timber frame. As there had to be clearance for moving the sashes it was impossible to make this window weathertight and because of the tendency of the sashes to rack, i.e. move out of the vertical, they were liable to jam and be difficult to open and close. This simple form of window is little used today.

The advantage of this type of window is that there are no internal or external projections from opening sashes and it can be opened to give reasonable control of ventilation. It is difficult to clean the glass both sides from inside and the clearance required for movement of the sashes makes it difficult to weatherseal for conditions of severe exposure.

A recent adaptation of the horizontally sliding window is the so called 'patio window' which is in effect a combined fully glazed door and window. The large area of glass provides daylight and a wide, full length view out. These patio windows or doors are made as two full height sliding sashes or frames, one or both of which slide horizontally on an overhead track from which the sash hangs and slide on guide runners at the bottom. Because of the large area of glass, double glazing units are used to reduce heat loss and weatherstripping is fitted around sashes to exclude wind.

Because of their comparatively flimsy construction in plastic or aluminium sections these doors are sometimes prised open to gain entry.

### Composite action windows

Composite action windows are designed to act like side-, top- or bottom-hung windows for normal ventilation purposes, by opening on pivots which can be unlocked so that the pivots then slide in grooves in the frame and open on hinged side stays to facilitate cleaning, as illustrated in Fig. 34. Of the three methods of opening, the top-hung projected window has been the most popular.

To clean this window the sash is projected to a horizontal or near horizontal position to clean the outside glass. The person cleaning will need to bear some of his weight on the open horizontal sash to reach the extreme outside edge and because of this there have been some

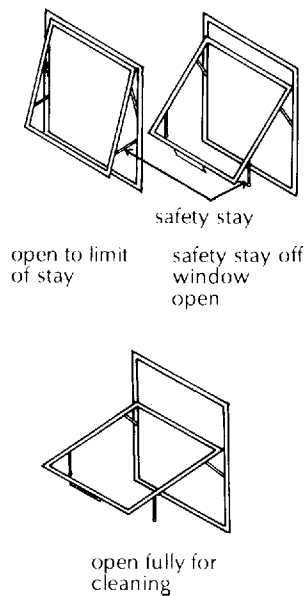


Fig. 34 Projected top-hung window.

### Tilt and turn window

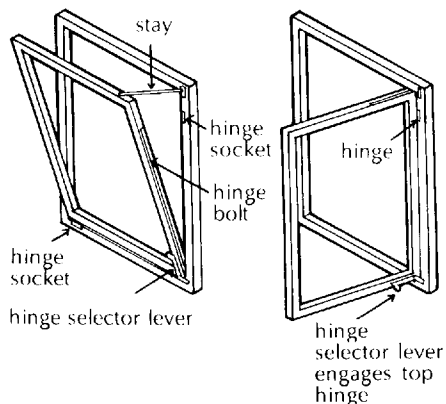


Fig. 35 Tilt and turn window.

### Sliding folding windows

serious accidents due to the supporting pivots coming out of the grooves.

The projected top-hung window can be projected down from the top of the window to allow both top and bottom ventilation.

This type of window was developed specifically to facilitate cleaning windows inside and out in conditions of comparative safety on upper floors of multi-storey blocks of flats. Because the sash may be projected into the room there is less danger of accidents than there is with a horizontally pivoted window.

The advantage of cleaning both sides of these windows from inside, by means of a long-handled squeegee if the sash is of any considerable size, should be weighed against the likelihood of the complicated mechanism becoming fouled and not operating properly.

A variation of the top-hung projected sash is the projected awning window in which three or more shallow sashes at high level open as if top-hung and can be projected for ease of cleaning from inside. The three sashes are ganged to open and be projected together through operating levers. Because of the comparatively shallow sashes each can be cleaned in safety from inside by hand.

This type of window is made specifically for ease of cleaning window glass both sides in safety, from inside the room. For normal operation the sash is bottom-hinged (hung) to open in for ventilation, as illustrated in Fig. 35. A stay limits the extent to which the head of the sash will open for safety reasons. The opening operation does not provide close control of ventilation, particularly in the gusty wind conditions common to upper floors of multi-storey blocks of flats.

For window cleaning the window can be converted to a side-hung sash when closed.

A lever operates to release bolts which disengage one bottom hinge and simultaneously shoots a side bolt in to engage a top hinge. The sash may then be opened in for cleaning glass both sides from within. In common with other bottom-hung sashes, opening in, the sash when open may foul curtains.

Due to misuse or lack of maintenance to provide free movement of bolts and hinges this type of window may jam shut.

The frame and sash can be made in wood, metal or plastic with sections similar to an ordinary opening-in hinged window but fitted with a handle that locks the side hinge pins, enabling the window to be opened for cleaning.

The sashes in this type of opening window are hinged to each other and fold horizontally in concertina fashion to one or both sides of the window to provide a clear unobstructed opening as illustrated in Fig. 36. This opening light system is used as either a horizontal window or fully glazed doors where indoor and outdoor areas can be combined.

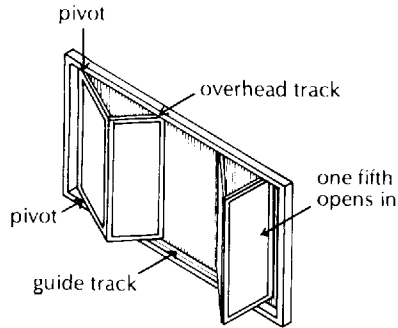


Fig. 36 Sliding folding sash window.

Each glazed sash is hung on a pivoted wheel that runs in an overhead track fixed to the top of the window frame. The lower edge of each sash is fixed to a pivoted wheel that runs in a track to guide the movement of the sash and maintain it in the vertical position.

A part of the width of each sash, when open, extends into the room, with the rest external so that the weight of the sashes is to some extent balanced each side of the overhead track.

This type of opening window is best suited for use as fully glazed doors giving access to balconies in warm climates, where a projecting overhead balcony gives some protection from rain and the clearance gaps top and bottom for the opening action may be acceptable.

Some maintenance is necessary to maintain the top track in working order and to clear the bottom track else the windows will be difficult to open. These windows are manufactured from steel or aluminium sections.

## WINDOW FRAMING

### Wood casement windows

Figure 37 illustrates the arrangement of the parts of a wood casement window, the members of the frames, casements and ventlights being joined with mortice and tenon joints. It will be seen that casements and ventlights fit into rebates cut in the members of the frame. These rebates, which are usually 13 mm deep, serve as a check to wind and rain in normal positions of exposure.

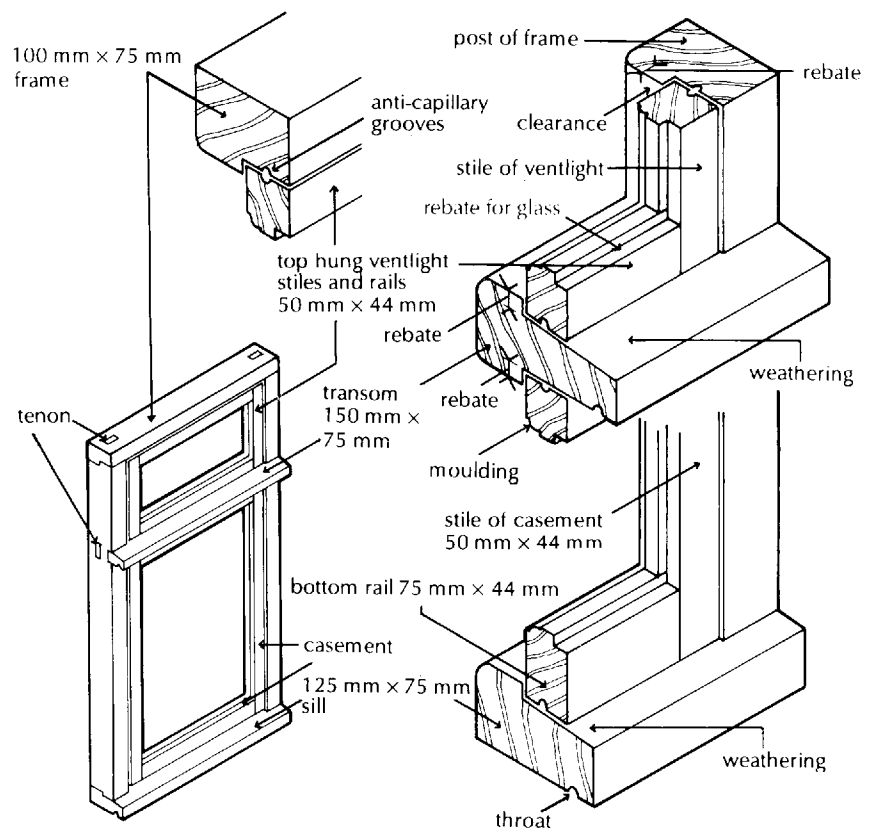
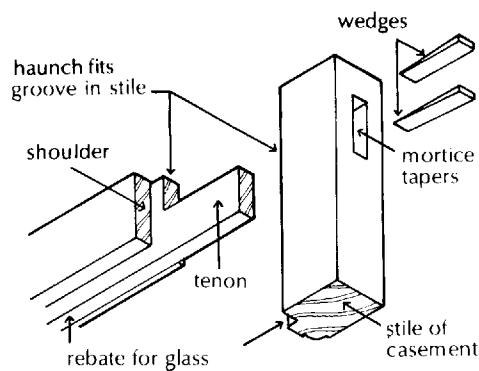


Fig. 37 Wood casement window.



**Fig. 38** Mortice and tenon joint.

To provide adequate strength and stiffness in the frame, casements and ventlights of casement windows and to accommodate rebates for casements and ventlights and for glazing, timber of adequate section has to be used and joined.

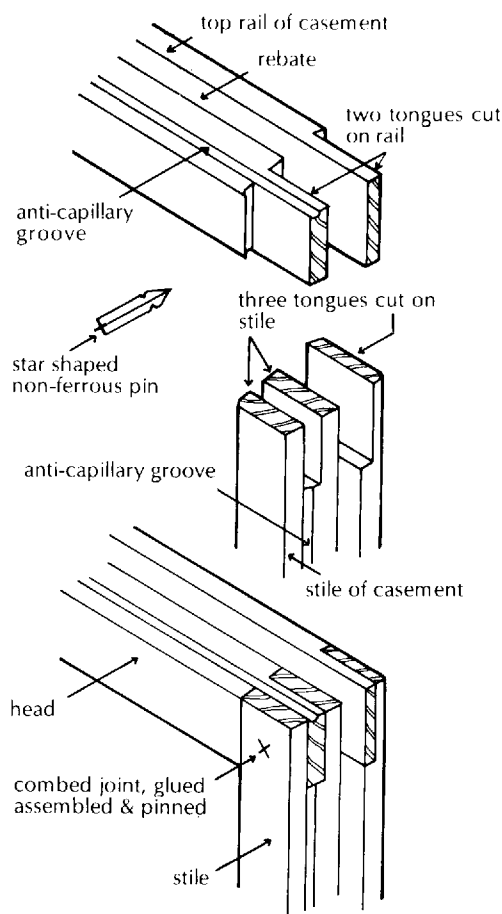
The traditional joint used is the mortice and tenon joint in which a protruding tenon, cut on the end of one section, fits into a matching mortice on the other, the joint being made secure with glue and wedges as illustrated in Fig. 38. This traditional wood jointing technique which is still to a considerable extent used was formed with hand tools to make a strong joint adequate for frames and casements.

The craft of accurately cutting and joining the timber members of windows and doors is termed joinery and those who practise it are called joiners. For centuries the joiner's craft was executed with hand tools used for preparing, cutting and assembling timbers. A mortice and tenon joint can readily be cut and made by skilled joiners and as it very rigidly joins timbers it was the joint always used in framing the members of windows and doors up to some seventy years ago.

During the present century woodworking machinery has been increasingly used to prepare, cut and assemble windows and doors so that today standard windows and doors are machine made. The skilled joiner can quickly cut and assemble a mortice and tenon joint but the time taken by machinery to cut and assemble this joint is greater than that required to cut and assemble a combed or dowelled joint. In consequence mortice and tenon joints are used less than they were.

The casements of mass-produced wood windows are joined with the combed joint illustrated in Fig. 39, which consists of interlocking tongues cut on the ends of members which are put together, glued and pinned. With the use of modern glue techniques this joint is as strong as a mortice and tenon joint. The combed joint is used in mass-produced windows as it can more rapidly be cut and assembled by woodworking and assembly machines than a mortice and tenon joint.

It is usual to specify the sizes of timber for joinery for windows, doors and frames as being ex 100 × 75 mm, for example. The description 'ex' denotes that the member is to be cut from a rough sawn timber size 100 × 75 mm, which after being planed on all four faces would be about 95 × 70 mm finished size. This system of specifying the sawn sizes of members is used when joinery is to be prepared by hand operated tools so that the member may be wrought or planed down to a good surface finish without limitation of a precise finished size, yet maintaining the specified size of window. Where joinery is wrought or planed by machine it is practice to specify the precise finished size of each member as this is the dimension the operator needs to know when setting up the machine and it is up to him to select the size of sawn timber to be used to produce the finished size.



**Fig. 39** Combed joint. Taken apart [top] and assembled [bottom].

## Casement

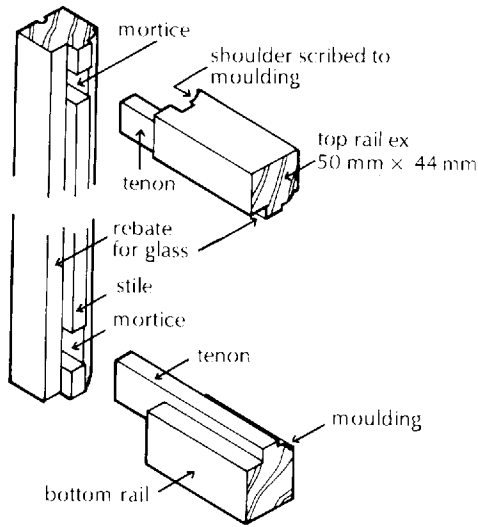


Fig. 40 Wood casement taken apart.

## Ventlight

A casement is framed from four members, the two vertical stiles and top and bottom rails. The stiles and top rail are cut from 50 × 44 mm timber and the bottom rail from 75 × 44 mm timber. In the selection of a section of timber suited to framing a casement a balance is struck between adequate width of section to make a sound mortice and tenon joint and least width to provide maximum glazed area and sufficient thickness for a glazing rebate.

The stiles and rails are rebated for glass and rounded or moulded for appearance sake. The rail ends are tenoned, shouldered and scribed to fit to the glazing rebate and moulding on the stiles. The rail tenons which are fitted to the mortices in the stiles are put together in glue, the tenons are wedged into the tapering mortices and the frame members are cramped tightly together until the glue has set.

The tenons are cut with their faces in line with the rebate for glass and moulding to minimise the number of faces cut across the grain. Figure 40 is an illustration of the framing members of a casement taken apart.

The four members of the ventlight are cut from timbers the same size as the stiles of the casement and are rebated, moulded and joined in the same way as the casement.

## Window frame

A casement window frame consists of a head, two posts (or jambs) and a sill joined with mortice and tenon joints, together with one or more mullions and a transom, depending on the number of casements and ventlights.

The members of the frame are joined with wedged mortice and tenon joints as illustrated in Fig. 41. The posts (jambs) of the frame are tenoned to the head and sill with the ends of the sill and head projecting some 40 mm or more each side of the frame as horns. These projecting horns can be built into the wall in the jambs of openings or they may be cut off on site if the frame is built in flush with the outside of the wall. The reason for using a haunched tenon joint between posts and head is so that when the horn is cut off there will still be a complete mortice and tenon left.

It will be seen from Fig. 41 that one face of the tenon is cut in line with the rebate for the casement. It is usual practice in joinery to cut one or both faces of tenons in line with rebates or mouldings to keep the number of faces cut across the grain to a minimum. The mortice and tenon joints are put together in glue, cramped up and wedged.

When there is a transom in the frame it is joined to the posts by means of tenons fitted and wedged to mortices. Mullions are joined to head and sill with tenons wedged to mortices and to the transom with stub tenons fitted into a mortice. A stub tenon is one which does not go right through the timber into which it is fitted.

The members of a wood window frame are cut from 100 × 75 mm or 100 × 63 mm for sill and transom.

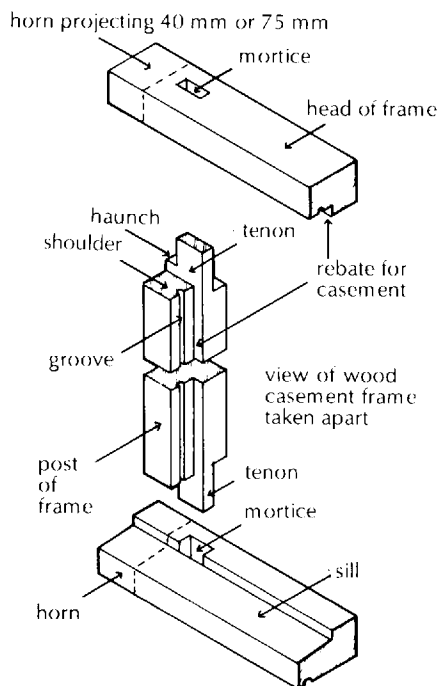


Fig. 41 Joints of casement window frame.



## Standard wood casement

The manufacturers of wood windows produce a range of standard windows. Standard sizes and designs are offered, the advantage being the economy of mass production. In line with the move to dimensionally co-ordinate building components and assemblies, some of the standard ranges of windows are designed to fit basic spaces, with such allowances for tolerances and joints as appropriate. The purpose of dimensional co-ordination is to rationalise the production of building components and assemblies through the standardisation of sizes, within a framework of basic spaces into which the standard components and assemblies may fit.

The difficulty has been to adapt this factory assembly technique to conditions on the average building site, without recourse to cutting components on site to fit and the use of gap-filling or gap-covering materials. The difficulty has yet to be overcome because of the deep-rooted tradition in building of roughly putting together and cutting and filling to make a fit.

The casements and ventlights are cut so that their edges lip over the outside faces of the frame by means of a rebate in their edges, as illustrated in Fig. 42. These lipped edges are in addition to the rebate in the frame so that there are two checks to the entry of wind and rain

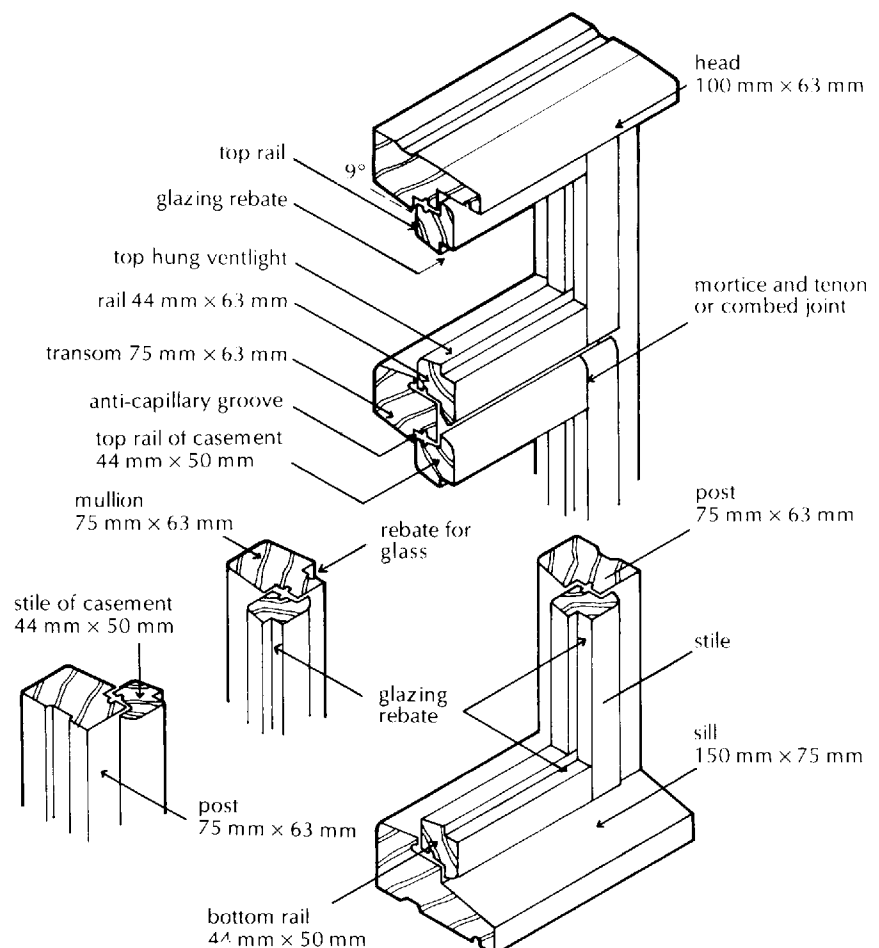


Fig. 42 Standard wood casement window.

between opening lights and the frame. The members of the frame and of the opening lights may be joined with mortice and tenon or combed joints.

## Weatherstripping

For some years now a largely urban, self-indulgent northern European population has grown accustomed to conditions of internal warmth more common to the Mediterranean climates that they seek on holiday and in retirement. Such conditions were alien to their ancestors who accepted the rigours of working outdoors in the damp cold weather, usual for a large part of each year. As a result there has been an increasing call on the limited sources of energy to provide heating.

Current building regulations set standards of insulation for the external fabric of new buildings which include a recommendation for the use of double glazing in windows to conserve energy resources. The majority of modern windows include systems of weatherstripping around all opening parts of windows to exclude wind, such as those illustrated in Figs 43 and 44. This weatherstripping serves as an effective seal against the uncontrolled exchange of cold outside and warmed internal air to the extent that rooms become 'stuffy' due to

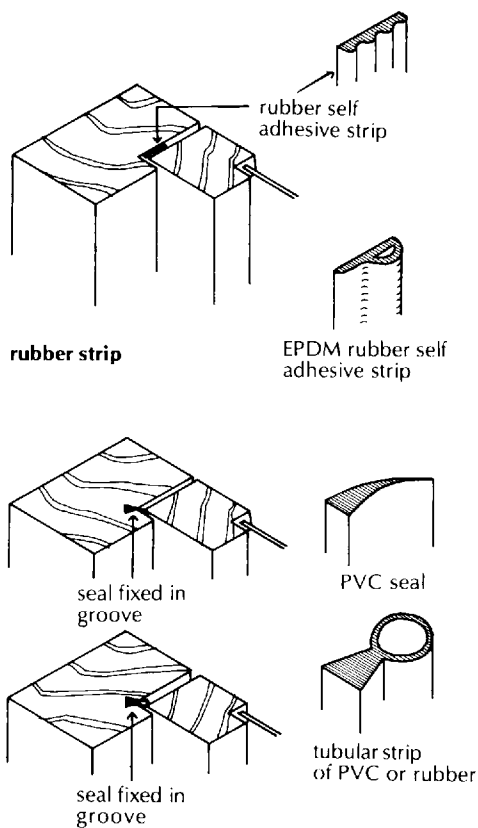


Fig. 43 Weatherstrips.

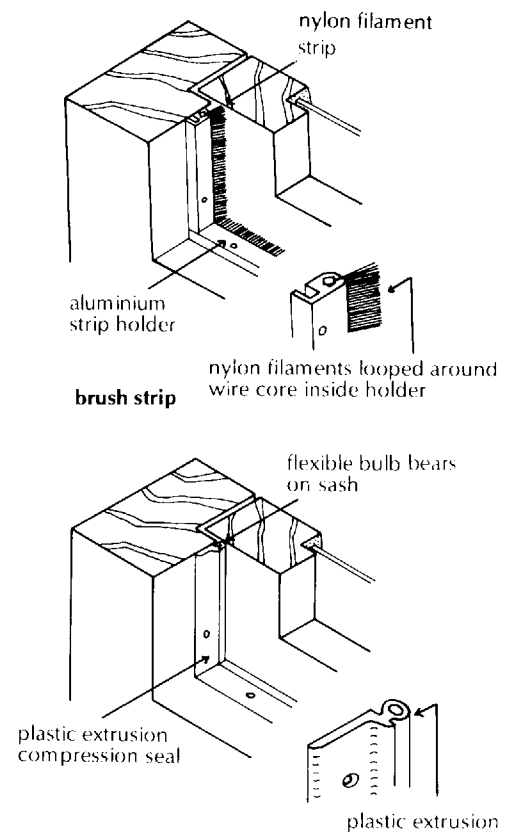


Fig. 44 Weatherstrips.

lack of ventilation. To counter this the most recent regulations require permanent ventilation.

In addition to acting as an effective barrier to the entry of draughts of cold air, the systems of weatherstripping also serve as an effective barrier to airborne sound.

In sheltered positions the outward facing rebate in the frame into which opening lights close will generally prevent rain penetration. The rebate will not, however, prevent draughts of cold air being blown through the clearance gaps around opening lights by wind pressure. To minimise cold draughts and to act as a seal against wind-driven rain in all positions of exposure, it is practice today to fit weatherstripping to all opening lights of new and old windows.

The two forms of weatherstripping that are commonly used are a flexible bulb or strip of rubber, synthetic rubber or plastic which is compressed between the frame and opening light (Figs 43 and 44) or a strip of nylon filament pile between the frame and opening light (Fig. 44).

For a maximum effect these seals should be fitted or fixed on the back face of the rebate or the inner face of the frame so that the rebate acts as a first defence against driven wind and rain.

The synthetic rubber strips illustrated in Fig. 43 are tacked inside the rebate of a wood window frame up to the outward facing rebate or may be self adhesive for fixing to metal or plastic windows. The advantage of these tacked in place or stuck on strips is that they can easily be replaced when they have lost elasticity in use. Of the two sections illustrated the bulb strip is probably the most effective.

The plastic strips illustrated in Fig. 43 are designed specifically to fit into shallow grooves in wood, metal or plastic windows. The strip is fitted to the dovetail groove with a machine that forces the end of the strip into the groove to make a tight fit. Because of the tight fit these strips are difficult to replace when they have lost elasticity.

The weatherstripping system illustrated in Fig. 44 consists of an aluminium section into which a strip of nylon filament is fitted. The aluminium section is tacked or screwed to the wood frame so that the flexible bulb bears on the sash when closed, as illustrated in Fig. 44.

Both weatherstripping systems illustrated in Fig. 44 are supplied mainly for fixing to existing windows.

## Hardware

### Hinges, fasteners and stays

Wood casements, ventlights and sashes are hung on a pair of pressed steel butt hinges similar to those used for doors. To inhibit rusting the hinges are galvanised and finished with a lacquer coating. As an alternative, metal offset hinges may be used for casements, in which the pin is offset outside the casement so that when the casement is

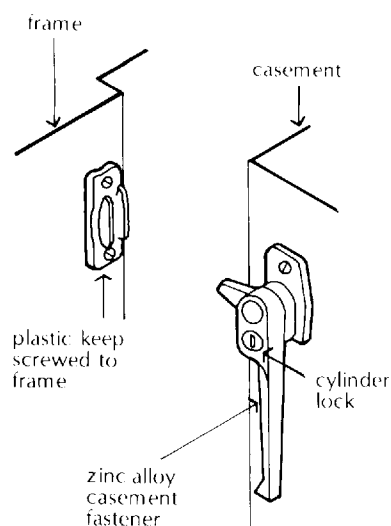


Fig. 45 Lockable casement fastener.

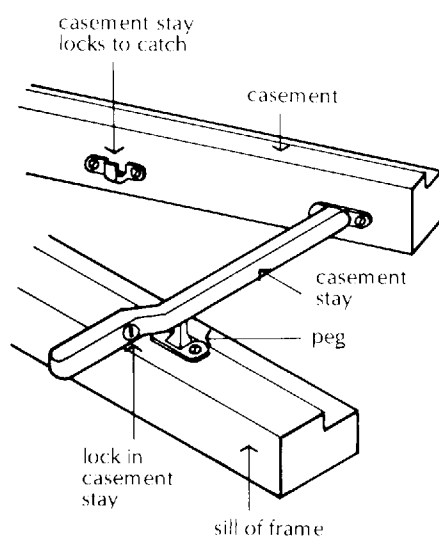


Fig. 46 Lockable casement peg stay.

open there is a gap between the hinged edge of the casement and the frame sufficient to allow for cleaning the outside of glass from inside the building.

To secure casements, sashes and ventlights in the closed position a casement or window fastener or latch is fitted halfway up the height of casements and in the centre of ventlights. These fasteners operate through a latch, which is fixed to the opening casement, and engages a keep fixed to the frame as illustrated in Fig. 45. The handle of the latch is raised to release the latch to open the window.

For security the majority of window latches are lockable by a loose key that operates a lock in the latch. Obviously the loose key should not be left in the lock when the window is closed as it would invite a break in by breaking the glass. Too often these small loose keys are mislaid.

Some care should be taken in fitting casement fasteners and keeps so that when the fastener is closed it firmly closes the casement on to flexible weatherstripping fixed in the rebate of the window frame around the opening light.

Casement fasteners are made of cast zinc, aluminium or steel, usually finished with a protective coating of anodising, powder or liquid organic coating or plastic.

To maintain opening lights in a window in a chosen open position, casement stays are fitted to the bottom rail of opening lights, as illustrated in Fig. 46. The conventional form of these stays is a casement stay fixed to the bottom rail of the sash, which engages a casement peg fixed to the sill of the window frame. Holes in the stay provide a selection of possible openings. The stay, which pivots in its fixing, can be secured in a catch, fixed to the bottom rail of the sash when the window is in the closed position.

Some casement stays have been designed to operate through the frictional resistance between a two piece stay to maintain the casement in a selected open position. These have not been particularly successful, as the frictional resistance required to maintain the casement in an open position in gusty wind conditions is such that it requires considerable force to operate the stay.

Stays are made of cast zinc, aluminium or steel usually finished to match the protective coating of fasteners.

## Fixing windows

The traditional method of fixing windows in position in a wall is to build solid walling around them. The window is said to be 'built-in'. The advantage of this is that there is a good fit of the wall to the window and that secure fixings may be solidly bedded in horizontal courses as the wall is raised around the window. The majority of softwood joinery and metal windows are built-in, as

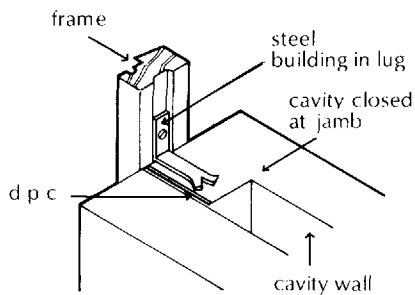


Fig. 47 Fixing wood window.

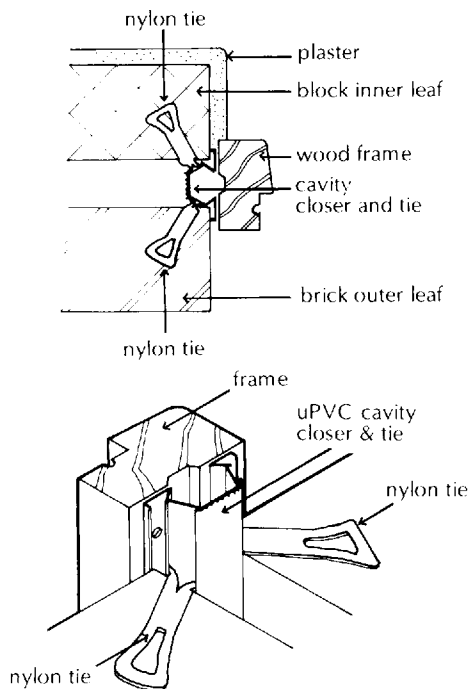


Fig. 48 uPVC cavity closer and ties.

## Perimeter sealing to wood windows

## Steel casement windows

any slight damage to the frame will be masked by subsequent painting.

The alternative method is to 'fix-in' the window after the wall has been built, which requires some care in building to ensure that there is sufficient clearance for fitting the window in position.

Hardwood windows are often fixed-in to avoid damage to the wood surface, which will not be covered with paint. Similarly ready glazed plastic and aluminium windows are fixed-in to avoid damage to surfaces and glazing.

Softwood window frames are secured in position in solid walls by means of 'L' shaped galvanised steel cramps or lugs that are screwed to the back of the frame and built into horizontal brick or block courses as the wall is raised. Figure 47 is an illustration of a fishtail ended lug 50 × 75 mm in size built into a horizontal course of a brick cavity wall.

Where the cavity of a wall is continued up to the jambs of a window opening, a system of plastic cavity closers and ties may be used. A preformed uPVC cavity closer is screwed to the back of the window frame as illustrated in Fig. 48. Nylon wall ties are slotted into the sides of the cavity closer and built into horizontal courses to secure the frame in place. One cramp, lug or tie is used for each 300 or 450 mm of height of window each side of the frame.

Where hardwood frames are fixed-in after the walling is completed, one method of fixing frames is to leave pockets in the jambs of the wall into which lugs can be fitted and the walling then made up. The term 'pocket' is used to describe the operation of bedding a few bricks in dry sand so that they may be removed after the wall is built for the building in of lugs at a later stage. As an alternative the window frames may be secured by galvanised iron straps screwed to the back of the frame and screwed to plugs in the inner reveal of the opening where they will be hidden by subsequent plastering.

Most wood window frames are bedded in mortar as the frame is built-in, with the mortar pointed as a perimeter seal. Where frames are fixed-in the gap between the back of the frame and the surrounding walling is sealed against weather with one of the elastic sealants described later.

The steel section window has lost favour principally because of the ill repute it gained from rapid deterioration by rusting, before the introduction of hot-dip galvanising in the 1940s. The strong slender sections of this type of window were at one time considered its most attractive feature. Changes in fashion mean that the steel window does not have the popularity it enjoyed between 1930 and 1950. The

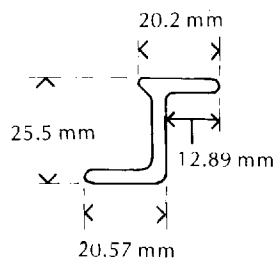


Fig. 49 Standard Z section.

disadvantages of the steel window are that the small section will not comfortably accommodate the thickness of double glazing, and the material being a good conductor of heat acts as a cold bridge to transfer of heat and encourages condensation which in turn may encourage rust.

Steel casement windows are made either of the standard Z section hot-rolled steel illustrated in Fig. 49 or the universal section illustrated in Fig. 50. The latter section is made with channels to take weatherstripping.

Standard steel casement windows are made from the hot-rolled steel Z section which is used both for the frame, casements and ventlights. The section is cut to length, mitred and welded at the corners. The assembled parts of the window are thoroughly cleaned and then 'rustproofed' by the hot-dip galvanising process in which the parts are dipped in a bath of molten zinc. The zinc adheres strongly to the steel in the form of a thin coating which protects the steel from corrosive rusting. This protective coating will be effective for many years, the effective useful life of the window depending on the thickness of the coating. The thicker the coating the longer the life.

The casement and frame sections fit together as illustrated in Fig. 51, making a reasonably close fit to exclude rain in all but exposed positions. Where there are a casement ventlight and dead light as illustrated in Fig. 52, two specially rolled steel sections are used as mullion and transom. The mullion section is scribed (cut) to fit to the profile of the frame and welded in position as is the transom which is welded to the mullion and the frame. The assembled parts are cleaned and hot-dip galvanised.

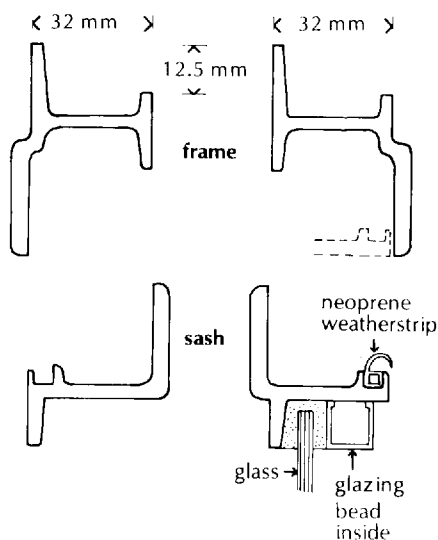


Fig. 50 W20 steel window sections.

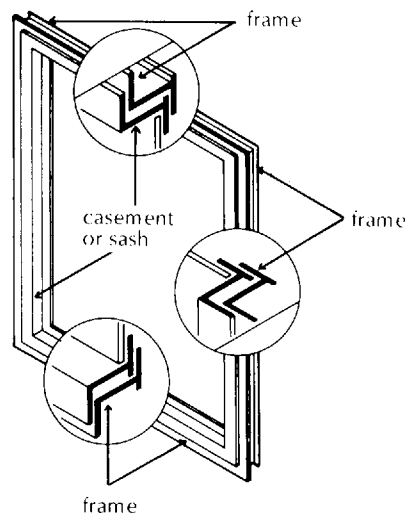
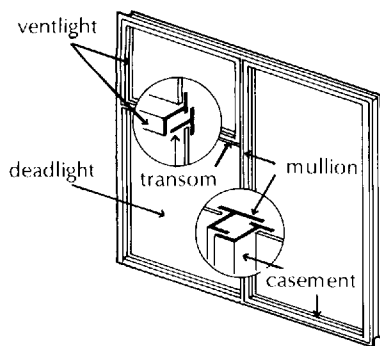


Fig. 51 Standard metal casement.



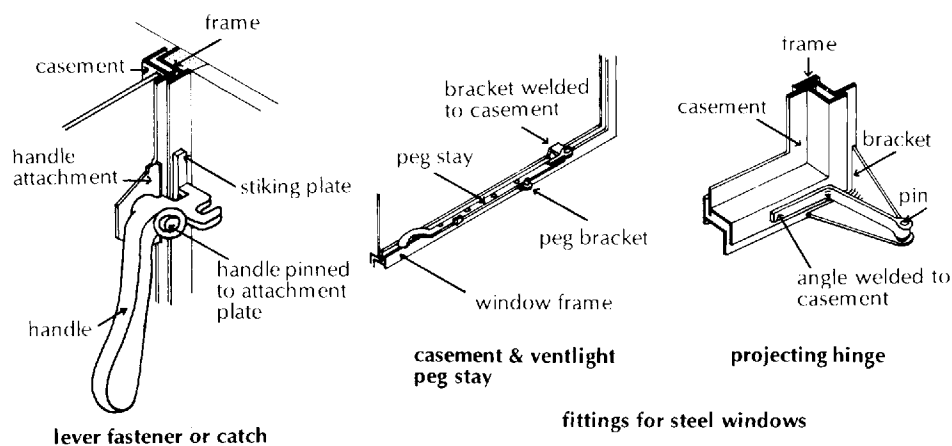
**Fig. 52** Standard metal window.

As an alternative to the standard Z section the universal or W20 steel section may be used. These heavier sections, illustrated in Fig. 50, may be used for frame, casements and ventlights with mullion and transom sections. The assembled parts are hot-dip galvanised after assembly. Universal sections are generally used for larger casement and pivoted windows where the greater variety of section available is of advantage in making up the more complicated requirements of frame and sash sections and for the fixing of weatherstripping and to accommodate double glazing units.

There is no straightforward method of overcoming the disadvantage of the conductivity of steel windows to the transfer of heat and the possibility of some condensation forming on inside faces, particularly in humid atmospheres such as kitchens and bathrooms. Where there is adequate ventilation in kitchens and bathrooms, condensation can be minimised and rust inhibited by sound protective coating. The comparatively small surface area of steel in these windows compared to the total area of outside walling will cause little significant loss of heat.

Steel casement windows are fitted with steel butt hinges or projecting hinges welded to the frame and opening lights. The projecting hinge illustrated in Fig. 53 is projected outside the face of the window by steel plate brackets and an angle which are welded to the frame. The pin around which the opening light hinges is offset so that when the casement is open there is a sufficient gap to make it possible to clean the outside of the glass from inside the room.

Lever fasteners and peg stays similar to those used for wood windows are welded to the frame and opening lights as illustrated in Fig. 53.



**Fig. 53** Hinges and fasteners.

## Fixing steel windows

Standard steel casement windows are usually built-in to openings in solid walls and secured in position with 'L' shaped lugs that are bolted to the frame as illustrated in Fig. 54. The lugs are adjustable to suit brickwork courses. Where these steel windows are fixed-in, after walls have been built, a galvanised steel lug is bolted to the back of the frame and its projecting arm is then screwed to a plug in the inner reveal of the wall. These lugs will later be obscured by plaster.

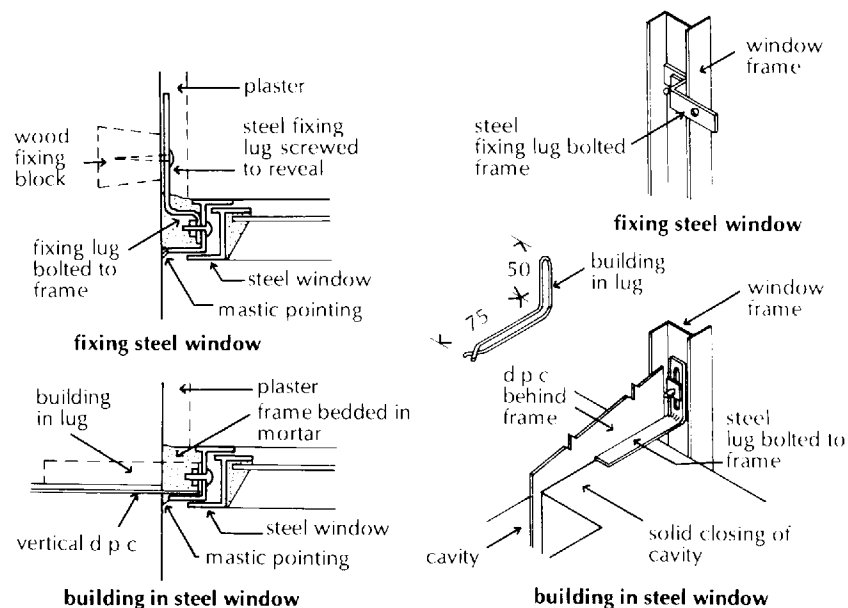


Fig. 54 Fixing steel windows.

Steel windows finished with hot-dip galvanising coating should be painted both as added protection against corrosion and as a decorative finish over the dull, grey, zinc coating.

As an alternative to painting, galvanised steel windows may be finished with a polyester powder coating to provide additional protection against corrosion and as a decorative finish.

The galvanised windows are cleaned, chromated and electrostatically coated with polyester powder which is then stoved at a temperature of 200°C. The usual colour of this coating is white, but black, red and Van Dyke brown are also used. The powder coating should not require painting for many years.

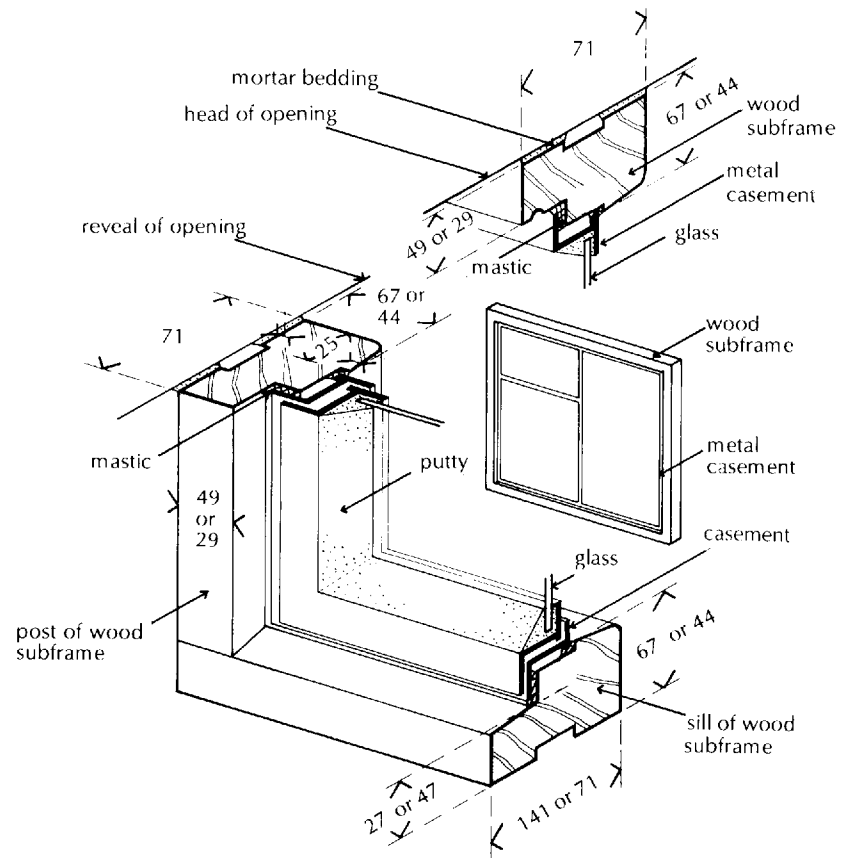
For unheated buildings such as warehouses and farm buildings, galvanised and powder coated steel windows will provide a perfectly adequate and durable source of daylight through walls.

## Timber sub-frame for steel windows

The sections used for steel windows are slender and may be damaged in transit or during handling on site. The manufacturers of these windows will supply wood surrounds for their steel windows to give added strength and rigidity or to provide a more substantial surround



to the window for appearance sake. The wood surrounds are usually cut from  $75 \times 75$  mm, or  $50 \times 75$  mm softwood timber which is wrought (planed smooth), rebated and joined with mortice and tenon or dowelled joints solidly glued. Figure 55 is an illustration of the section of a wood surround with the steel windows in position.



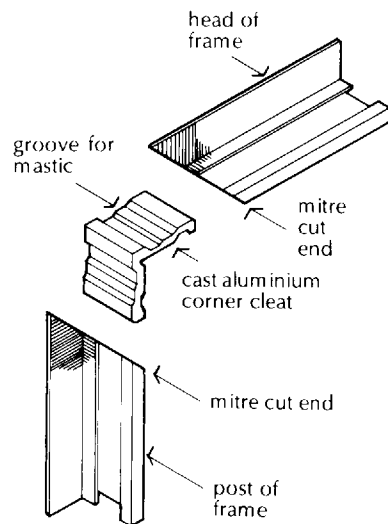
**Fig. 55** Timber sub-frame for metal window.

The steel window is secured to the wood surround with counter-sunk headed wood screws driven through holes in the steel frame into the wood sub-frame. Mastic is packed between the steel frame and the timber sub-frame to exclude rain. The two rebates cut in the wood sub-frame are so spaced that they accommodate the flanges of the steel frame. The wood surround is secured with L-shaped lugs or ties that are screwed to the back of the frame and built into horizontal joints of brick or blockwork.

The particular advantage of the wood surround is that it provides an appreciable surface around the slim section of metal which gives emphasis to the windows.

Steel windows and sub-frames for steel windows are usually built-in as the surrounding walls are raised and are bedded and pointed in mortar as a perimeter seal. Where these windows and their sub-frames

## Aluminium casement windows



**Fig. 56** Corner cleat for aluminium window.

are fixed-in to prepared openings, so that coatings are not damaged, the perimeter seal is made with a sealant in the same way that aluminium windows are finished.

Aluminium windows were originally made as a substitute for hot-rolled steel section windows, in small sections similar to those of steel. Aluminium windows of small solid sections are less used now than they were, partly due to changing fashion and more particularly because the small section, which acts as a thermal bridge to encourage condensation, does not take the wider, double glazed, insulated glazing (IG) units in use today.

The majority of aluminium windows that are made today are of sections extruded from aluminium alloy in a wide range of channel and box sections with grooves for lips for weatherstripping and double glazing.

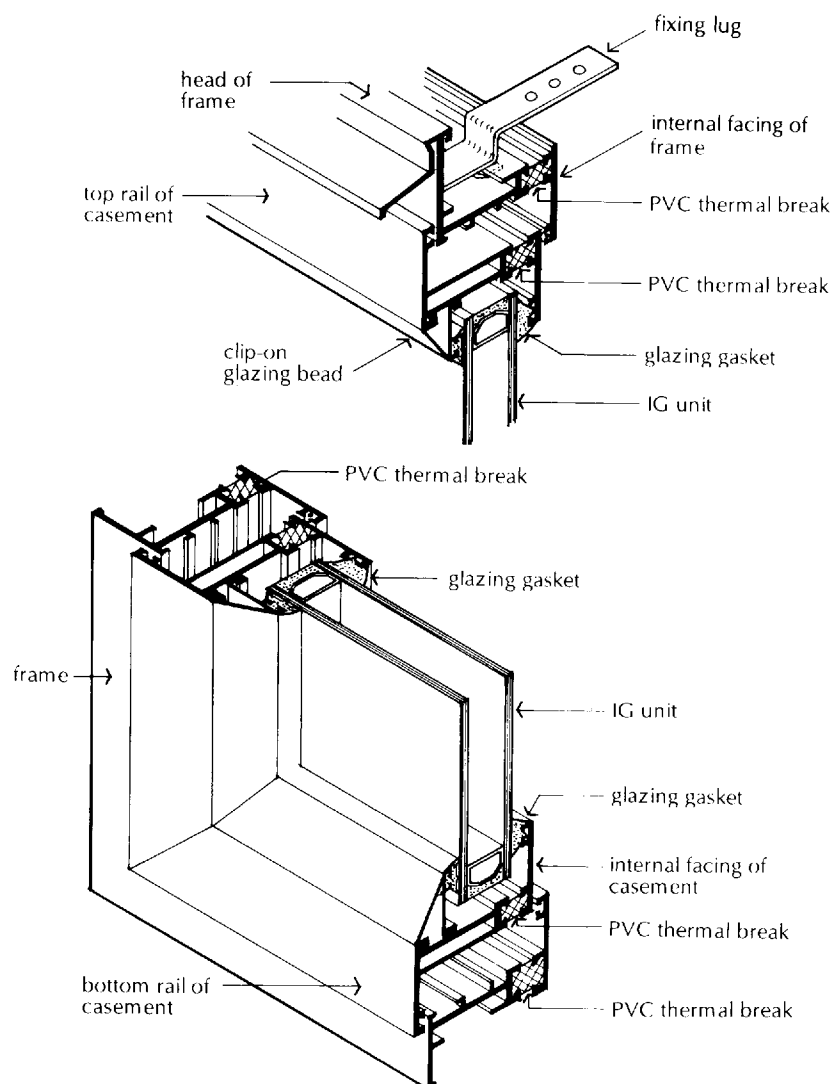
In the extrusion process through which these window sections are formed, molten metal is forced through a die as thin sections of material. The extrusion process allows for a wide range of sections which are more straightforward to vary than comparable uPVC sections. This is a particular advantage of aluminium as a window material where special sections are required.

The sections are mitre cut and mechanically cleated or screwed at joints which are sealed against entry of water as illustrated in Fig. 56. The fabricated frames and opening lights are then given a protective coating by anodising, polyester powder or liquid organic coating.

A disadvantage of aluminium as a window material is that it is a good conductor of heat and in consequence moisture vapour in warm air will condense to water on the cold inner surfaces of these window sections in periods of cold outside temperature. In most rooms this condensation on the comparatively slim sections will be merely a nuisance. In rooms such as kitchens, where air will be heavily saturated with moisture vapour, the condensation may spoil decorations and affect the seal to double glazing. Here it is advantageous to use the 'thermal break' window construction illustrated in Fig. 57. Separate aluminium window sections are mechanically linked to the main window sections, through plastic thermal break sections. The IG, double glazed units are secured with aluminium beads and the window is weatherstripped with preformed synthetic rubber seals.

## Fixing

The aluminium frame is secured to the surrounding wall by aluminium lugs that clip to the back of the frame at centres of up to 600 mm and also adjacent to hinges and fasteners, with the lugs screwed to plugs in the wall.



**Fig. 57** Thermal break aluminium casement window.

## Hardware

Hardware of hinges, lockable casement fasteners and stays is made of anodised finish, cast aluminium or die-cast zinc alloy, chromium plated.

## Protective coating

On exposure to air aluminium forms an oxide, surface coating which is a coarse textured light grey finish. This coarse surface will attract grime which is difficult to clean. Because of the unattractive appearance of the natural oxide finish, aluminium window sections are usually finished with anodised, polyester powder or liquid organic coatings as protection against oxidation and as a decorative coating that can be easily cleaned.

## Anodised finish

An aluminium oxide coating is formed by the sulphuric acid electrolytic method. Metal oxides are deposited on the surface of the

aluminium as an alternating current is applied across the bath of sulphuric acid. A limited range of colours can be produced by various electrolytes. The usual range of colours is from silver grey through bronze to black. The anodised finish is covered with a clear, thin coating of lacquer to protect it against alkaline materials used in building operations.

In the past some anodised finishes have failed due to the finish being damaged by building operations or other causes, and unsightly corrosion of the aluminium below has occurred and spread. Because of this and the limited colour range, anodised finish is less popular.

### **Polyester powder organic coatings**

After the window frames and opening lights have been cleaned, etched and chromate, conversion coat treated, the polyester powder is sprayed on to the windows. The coating is then stoved at 200 °C to form a hard, smooth, durable coating.

### **Liquid organic, acrylic coating**

After pre-treatment the same as that for the powder coating, the acrylic is applied in liquid form by electrophoretic dip for white or by electrostatic spray for colours. The liquid finish is then stoved at 200 °C to form a hard, smooth durable coating.

A range of bright colours is practical with both the polyester powder and the liquid acrylic coatings, from white through blue, green, red and black. These organic finishes provide a decorative, protective, durable coating that requires only occasional cleaning with water to remove grime. In time the stronger colours may bleach due to the effect of ultra-violet light.

### **Perimeter sealing around frames**

Wood windows that are built-in provide a wide flat surface between the back of the frame and the jamb of the surrounding wall that can be filled with mortar to exclude rain.

The thin-walled section and hollow at the back of both aluminium and plastic windows do not provide the facility for filling with mortar. These window frames require sealing around their edges with one of the sealants.

## **SEALANTS**

A sealant is a material that is initially sufficiently liquid or plastic for application and which cures or changes to a material that will adhere to surrounding surfaces, retain its shape and accommodate some small movement without loss of seal against wind and rain.

### **Plastoelastic sealant**

Sealants used for sealing perimeter joints around window frames are classed as plastoelastic, elastoplastic or elastic. Plastoelastic sealants, which have some elastic property, remain predominantly plastic and can be moulded.

**Elastoplastic sealant**

Elastoplastic sealants, which develop predominantly elastic properties as they cure, will return to their former shape when stress is removed and also retain some plastic property when stressed over long periods.

**Elastic sealant**

Elastic sealants will, after curing, have predominantly elastic properties in that they will continue to resume their former shape once stress is removed, during the anticipated useful life of the material.

**Acrylic****Polysulphide****Polyurethane****Silicone**

The materials that may be used for perimeter sealing around window and door frames are acrylic, polysulphide, polyurethane and silicone. Of these acrylic is classed as plastoelastic, polysulphide as elastoplastic and polyurethane and silicone as elastic. In general the plastoelastic material is easier to use because of its predominantly plastic nature, but it will not form so tough and elastic a surface as elastoplastic materials that have some plastic property. The elastic materials need some experience and skill in use for successful application.

**One-part sealant**

Polysulphide and polyurethane sealants are produced as either one-part sealants ready to use, or as two-part sealants which have to be mixed before use. The one-part sealants are more straightforward to use as there is no mixing and the material cures or loses plasticity fairly slowly, allowing adequate time for running into joints and compacting by tooling.

**Two-part sealant**

The two-part sealants require careful, thorough mixing and as they cure fairly rapidly require skill in application. The advantage of the two-part sealants is that as they cure fairly rapidly they are less likely to slump and lose shape and adhesion than the more slow curing one-part sealants. Silicone sealants which cure fairly rapidly to form a tough, elastic material require rapid application and tooling for compaction.

As the prime function of a sealant to perimeter gaps around window frames in traditional walling is as a filler to exclude wind and rain, it should adhere strongly to enclosing surfaces, be resistant to the scouring action of weather and sufficiently elastic to accommodate small thermal movements for the anticipated life of the material. The expected useful life of sealants, after which they should be renewed, is up to 15 years for acrylic and up to 20 years for

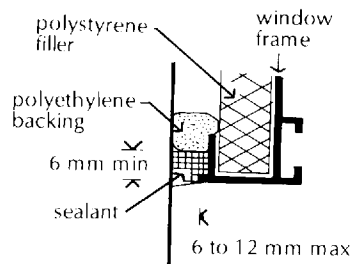


Fig. 58 Butt joint.

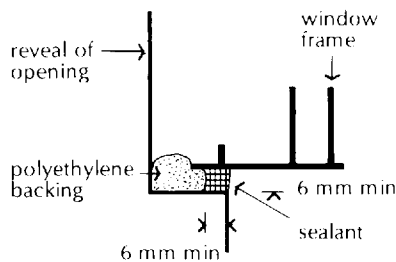


Fig. 59 Sealed lap joint.

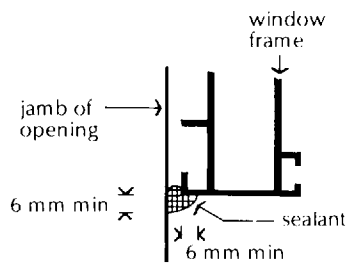


Fig. 60 Fillet seal.

polysulphide, polyurethane and silicone. For appearance, the sealant should not be too obvious.

To ensure maximum adhesion, the surfaces on to which a sealant is run should be clean, dry and free from dust, dirt and grease. Rough surfaces such as open textured brick, textured rendering, scratched finishes and textured masonry paints are unsatisfactory as a base; the sealant will not readily adhere and would produce an unsightly appearance. Some window surfaces such as aluminium and plastic will require solvent cleaning to remove oil, grease and other coatings if the sealant is to make satisfactory adhesion. Sealants are usually run into joints from a gun operated by hand pressure or air pump.

The form of sealant joint used depends on the width of the perimeter gap between window frame and surrounding wall and whether the frame is set in a rebate. The types of joint used are butt joint, lap joint and fillet seal. The most commonly used is the butt joint (Fig. 58), formed between the back of the frame and the reveal of the opening. Foamed polyethylene is first run into the gap as a backing for the sealant. The sealant is then run into the joint and tooled with a spatula to compact the material and make good adhesion to the two surfaces. It is finished with a slight concave finish up to the edge of the window frame.

The best gap width for the joint is from 6 to 12 mm which is wide enough for application of the sealant, small enough to contain the sealant and not too obvious. Butt joints up to 25 mm are practical with the depth of the sealant being half that of the gap. These wider joints tend to look somewhat unsightly. To prevent the sealant adhering to the outside face of the window frame it is good practice to use masking tape up to the edge of the outside face of the frame. Once the sealant is sufficiently cured the masking tape is stripped towards the sealant. Polysulphide or polyurethane two-part sealants are commonly used by skilled operatives.

A lap point is formed where the window frame is set behind an accurately formed rebate in wood, metal, masonry or concrete surrounds (Fig. 59). The sealant is run into the gap over a polyethylene backing and tooled to a slight concave finish to masking tape. It is more difficult to form or renew this joint, which is less obvious than a butt joint.

A gap of less than 6 mm between the window frame and the opening in the wall is too narrow for gunned in sealant. Here a fillet seal is used, which is formed to adhere to the outside face of the frame and the wall opening (Fig. 60). The fillet seal is run as a convex fillet to provide sufficient depth of sealant, which is finished as it comes from

the gun. This type of sealant finish tends to have a somewhat untidy appearance.

## **uPVC casement windows**

These windows are fabricated from extruded, high-impact strength, white, uPVC (unplasticated polyvinyl chloride). Modifiers, such as acrylic, are added to the PVC material to improve impact strength. Pigment may be added to produce body coloured uPVC. The heated, plastic material is forced through dies from which it extrudes as thin-walled hollow box sections, complete with rebates, grooves and nibs for beads, weatherseals, glazing seals and for fixing hardware.

The wide range of sections are made in multi-cell form for rigidity, with one main central cell and two or more outer or surrounding cells. Main wall thickness varies from 3 mm for the bulkier German section, 2.8 mm for British and 2.2 mm for some French sections.

Tests for uniformity of section, colour and freedom from visible distortion of surfaces are carried out by reputable extruders. The dozen or so extruders in this country produce some hundreds of differing profiles. Some extruders also fabricate uPVC windows. The majority of the 6000–7000 fabricators take their sections from the handful of extruders.

## **Metal reinforcement**

The extruded sections are mitre cut to length, metal reinforcement is fitted and secured inside the main central cell, and the corner joins are welded together by an electrically heated plate that melts the end material, with the ends then brought together to fuse weld. The process of cutting and welding is fully automated, which makes it a comparatively simple operation to set the machine to make one-off sizes of windows for the replacement window market. This advantage is singular to uPVC windows.

## **Mitred, welded corners**

At the mitred, welded corner joints a rough, curled edge of weld material protrudes from the face of the sections. This excess material is cut away for appearance, either flush with the external faces or more usually as a shallow groove, the material around the joint being routed out to a depth of about 0.25 mm. This latter finish tends to mask the slight difference in texture at the joint more than the flush finish.

Reinforcement is fixed inside the hollows of the uPVC cells to

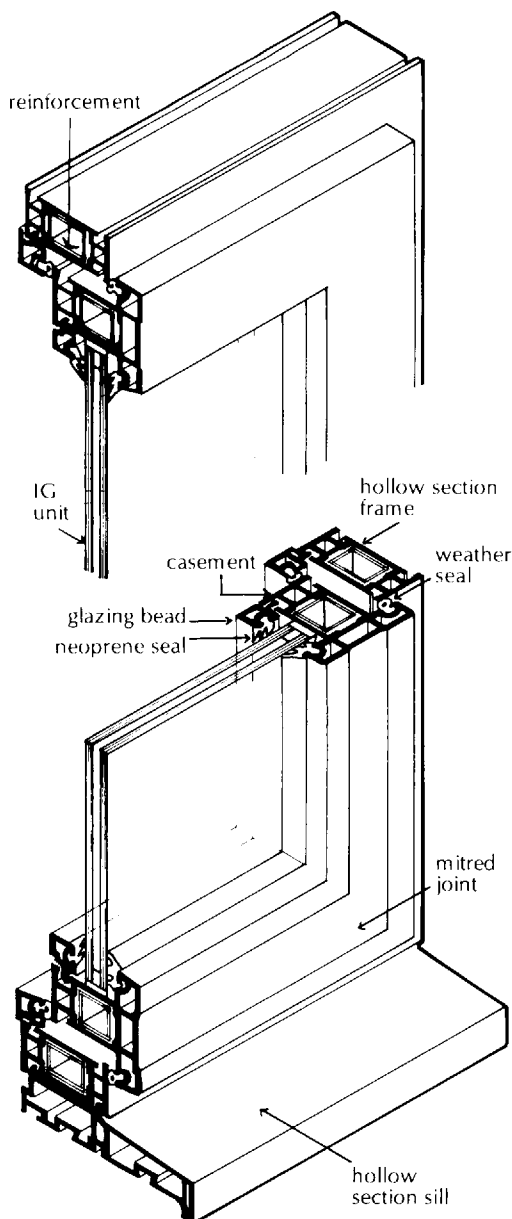


Fig. 61 uPVC casement window.

## Hardware

## Fixing uPVC frames

provide rigidity to the sections that might otherwise distort due to thermal movement, handling, fixing and in use as opening lights. Reinforcement should be fitted to all frames more than 1500 mm long and all opening lights more than 900 mm long. For fixing frames to surrounding walls and for secure fixing of hardware it is advantageous to use reinforcement to all window sections.

Reinforcement is either of galvanised, rolled steel or extruded aluminium sections, aluminium having the advantage that it does not destructively corrode and expand where water may find its way into the hollow sections.

In use, coloured uPVC material, particularly dark colours, may bleach in an irregular, unsightly manner after some years due to ultraviolet light, so white to off-white uPVC is recommended.

In fire, uPVC, which does not readily ignite, will only burn when the source of heat is close to the material and will not appreciably contribute to the spread of flame. The rate of generation of smoke and fumes produced when uPVC is subject to fire is no greater than that of other combustible materials used in building. Recent reports from Germany of the dangers of toxic fumes from these windows in fires, were given publicity to the extent that some German authorities did for a time ban their use. In the event it has been established that PVC gives no more toxic fumes than other materials that may ignite in fires and is thus but a part of the hazard of fire.

Other than occasional washing with water to remove dirt these windows require no maintenance and this is their principal advantage.

The uPVC casement illustrated in Fig. 61 is glazed with an IG double glazed unit set in synthetic rubber seals and fitted with weatherstripping and reinforcement of galvanised steel or aluminium sections.

Because most uPVC sections are bulky they are not suited for use in the comparatively small casement window. The extruders of uPVC sections make a less bulky section specifically for use in casement windows.

Hardware is made from cast aluminium alloy and die-cast zinc alloy with anodised, powder or organic liquid coatings for lockable fasteners and stays that are screwed through the outer wall of the uPVC sections into the reinforcement.

To avoid damage to the frames during building operations these windows are usually fixed in position after the surrounding walls have been built. Fixing is usually by driving strong screws through holes in the frame and reinforcement into surrounding walls or by means of



lugs bolted to the back of frames which are screwed to plugs in walls. Fixings are at 250 and 600 mm centres and from 150 to 250 mm from corners.

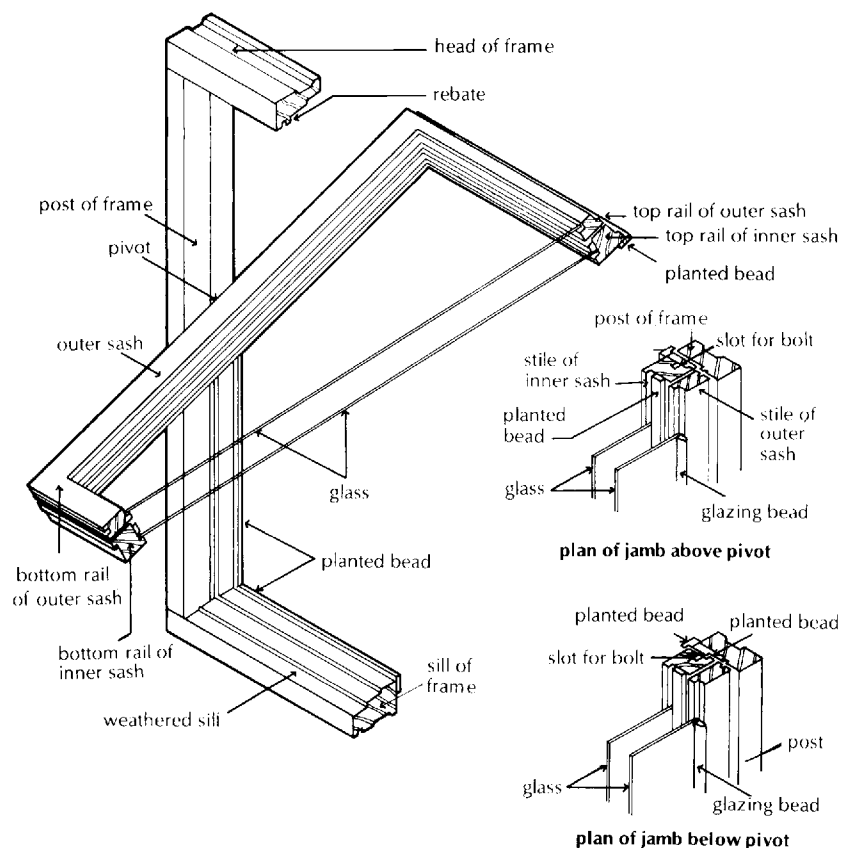
## Perimeter seals to uPVC windows

The gap between the window and the surrounding wall is sealed with silicone or polyurethane sealant with backing of foamed, compressible, pre-formed strips or gunned in expanded, adhesive foam for joints more than 6 mm wide.

## Pivoted windows

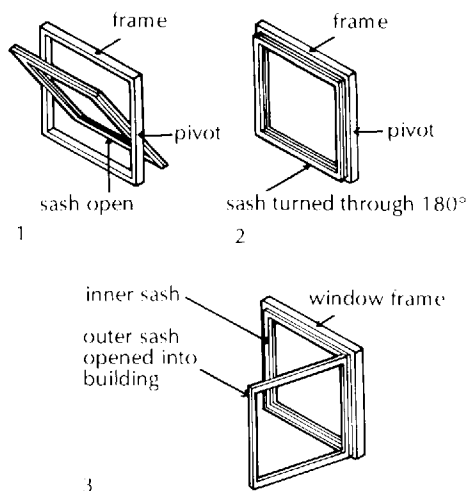
### Horizontally-pivoted wood window

Figure 62 is an illustration of a double-glazed horizontally-pivoted wood window. The frame is solid and rebated. Stop beads are fixed to the sash above and the frame below the pivots. The sash is made as separate inner and outer sashes, each of which is glazed and the sashes are normally locked together.

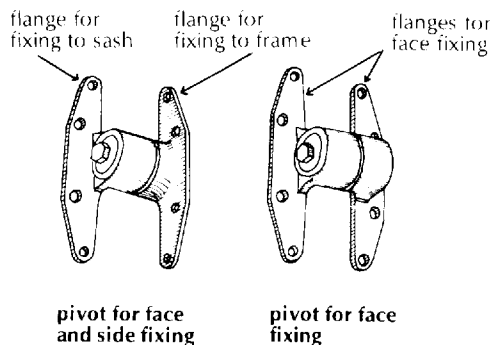


**Fig. 62** Horizontally-pivoted reversible window.

The purpose of forming the sash as two separate parts is so that the two parts of the sash may be opened for cleaning glass inside the space between the two parts. This is achieved by reversing the sash through 180° so that the outer part of the sash may be unlocked and hinge to



**Fig. 63** Sash reversed for cleaning glass.



**Fig. 64** Pivots for horizontally pivoted windows.

## Vertically pivoted steel windows

open into the room as illustrated in Fig. 63. In this position both sides of the glass in the outer part of the sash and the side of the glass of the inner part, facing the air space, may be cleaned in safety from inside the building.

The window is opened against the action of the friction pivots illustrated in Fig. 64 and locked shut with lever operated espanolite bolts that secure the sash at four points, top and bottom, against weatherstripping.

This may seem a somewhat complicated window construction when the majority of pivot windows today are supplied with IG units.

The advantage of a system designed for safety in cleaning glass and freedom from the need to replace faulty double glazing units at comparatively frequent intervals should be weighed against the somewhat complex construction.

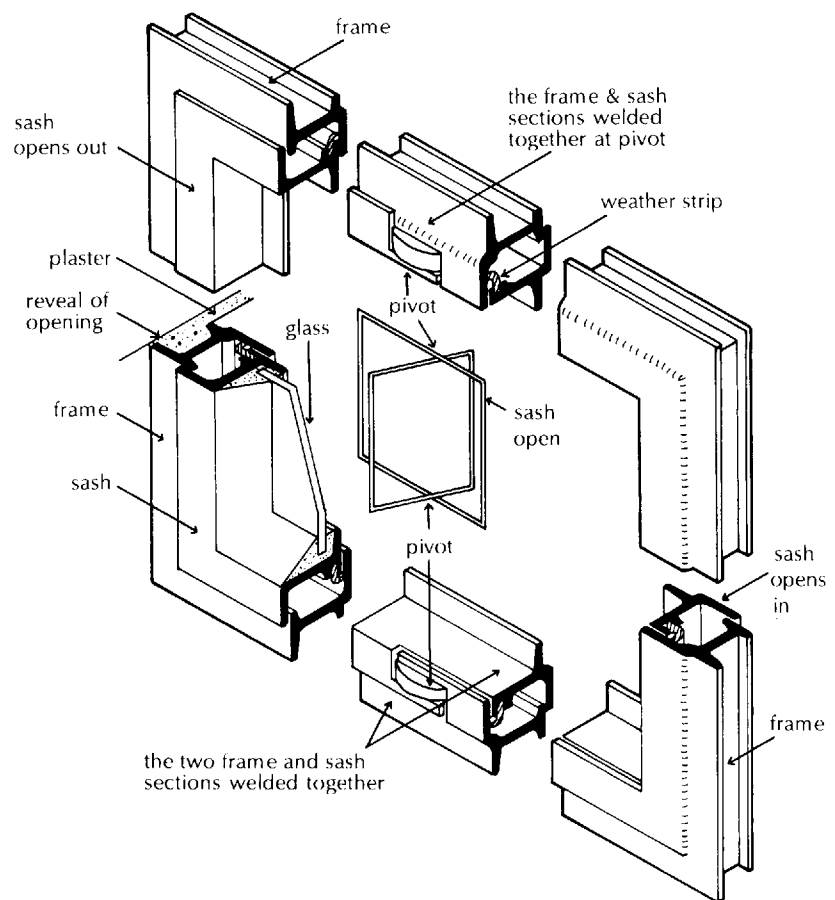
Because the friction pivots must not be too stiff to make opening difficult they may not be strong enough to resist gusts of wind in exposed positions; it is necessary to fit some form of stay.

The majority of windows fixed in recent years are glazed with IG units. The perimeter of the units is sealed around the two sheets of glass and the space between them to exclude moist air that might cause condensation on the inner face of the two sheets of glass.

Many suppliers of insulated glazing units give an assurance and guarantee that their units will maintain the perimeter seal and so prevent the entry of moisture and condensation on the inner faces of glass for up to 20 years. It is of little use the building owner calling in the guarantee if the units fail after some few years as many of the suppliers go into liquidation well before the expiry of the guarantee.

Figure 65 is an illustration of a steel section, hot-dip galvanised pivot window. The frame and sash of this vertically pivoted window are fabricated from universal sections that are welded together at angles and each side of the pivot where different sections join. The frame is fitted with compression weatherstripping to bear on and seal the clearance gap between frame and sash. The sash is pivoted so that two thirds of the width opens out and one third in, to minimise internal obstruction.

Providing the steel sections are adequately galvanised and protected with paint or a coating this window should survive the useful life of most buildings. The cold bridge effect of the thin metal sections is unavoidable with this material.



**Fig. 65** Vertically pivoted steel window.

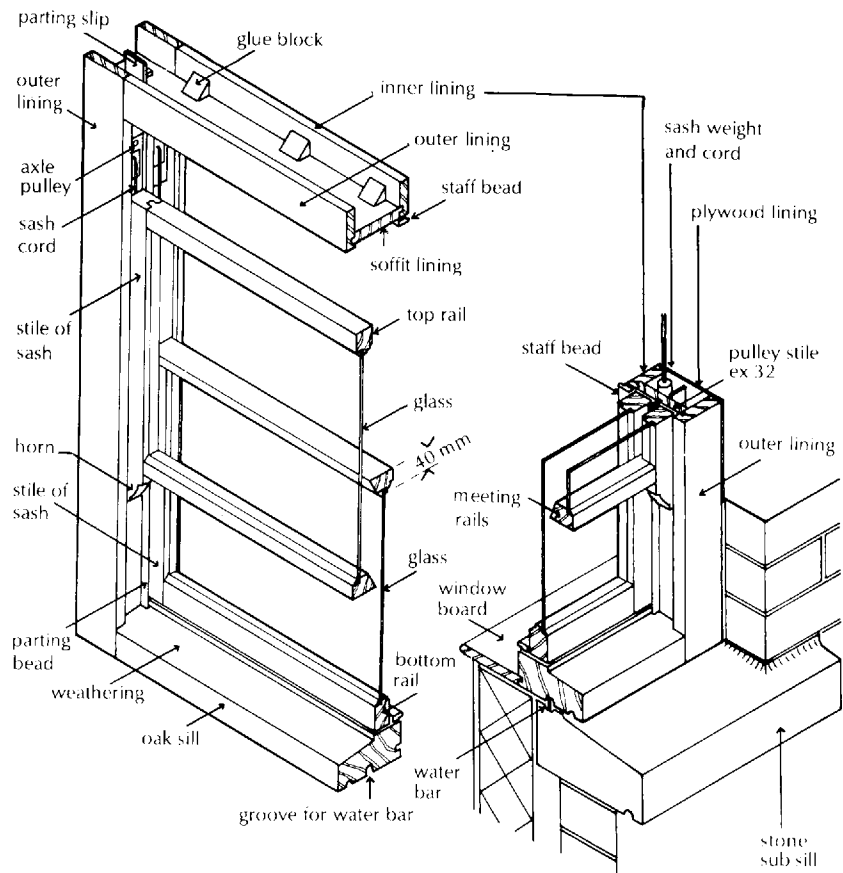
## Sliding windows

### Vertically sliding wood sash window (double-hung sash)

This traditional window is framed from thin section timbers to form a box or cased frame inside which the counterbalance weights are suspended to support the sliding sashes which are suspended on cords that run over pulleys fixed to the frame.

The jambs of the frame are cased from three thin members tongued, grooved and glued together as illustrated in Fig. 66. The pulley stile, in which the pulley supporting the sash cords is fixed, is usually 7 mm thicker than the outer and inner linings because it carries the weight of the sashes and the weights. A thin strip of wood, the parting slip, is suspended inside the cased jambs to separate the weights of the sashes. A strip of plywood or hardboard is nailed across the back of the linings as a back lining, to prevent the weights catching the reveals of the opening.

The size of the cased jambs depends on the thickness of the sashes. If the sashes are cut from 38 mm thick timbers the inside of the cased jamb is usually 85 mm wide and 50 mm deep, and the sashes cut from 44 mm thick timbers, 105 mm wide and 50 mm deep. The head of the cased frame is usually constructed from three thin members put together with glued tongued-and-grooved joints, or a solid rectangular section of timber 38 mm deep may be used.



**Fig. 66** Wood vertically sliding (double-hung) sash window with cased frame.

The sill of the frame is cut from a solid section of hardwood, such as oak, 75 mm deep and as wide as the cased frame overall. The sill is weathered and sunk on its top surface. The word weathered denotes that the top surface of the sill is cut to slope outwards to throw rainwater off. The sinking, which is a shallow rebate some 6 mm deep in line with the face of the lower sash, serves to prevent rainwater being blown between the sill and the sash. A 12 mm wide semi-circular groove on the underside of the sill forms a throat-and-drip edge and the rectangular groove takes a  $25 \times 3$  mm galvanised steel or wrought iron water bar which is bedded in mastic in the oak sill and in cement in the stone sub-sill. The head of the frame, which is cut to fit between the linings of the jambs and the pulley stile, is tongued to a groove in the soffit lining. Similarly the sill is cut to fit between the jamb linings, and the pulley stile is wedged into a groove in the sill. The outer linings of the jambs and head project 13 mm beyond the face of the pulley stiles to act as guides for the top sash. Parting beads  $10 \times 32$  mm are set into grooves in the pulley stiles to separate and act as guides to the sashes, and a staff bead is screwed to the edge of the inner linings to act as a removable guide for the lower sash. Brass axle pulleys, two to each sash, are fixed in the pulley stiles as illustrated in Fig. 66.

To renew sash cords, the staff beads and parting beads are removed and the sashes are lifted out into the room. Small traps cut in the bottom of the pulley stiles, called pockets, are taken out so that the new sash cords can be attached to the weights inside the cased frames.

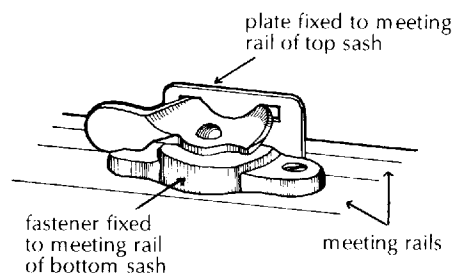
Sashes are usually of the same depth so that the meeting rails come together in the middle of the height of the window.

The stiles and top rail of sashes are cut from 38 or 44 mm thick  $\times$  50 mm deep timbers, rebated for glass and moulded inside. Meeting rails are cut from 63  $\times$  38 mm timbers rebated and splayed to meet and rebated for glass. The bottom rail of bottom sashes is cut from timber 38 or 44 mm thick  $\times$  63 or 75 mm deep, rebated for glass and moulded. The top rail of top sashes and bottom rail of bottom sashes are tenoned, wedged and glued to mortices in the stiles, and the meeting rails, which are tenoned to the stiles, are extended as horns to make a tenon the full depth of the thin meeting rails as illustrated in Fig. 66.

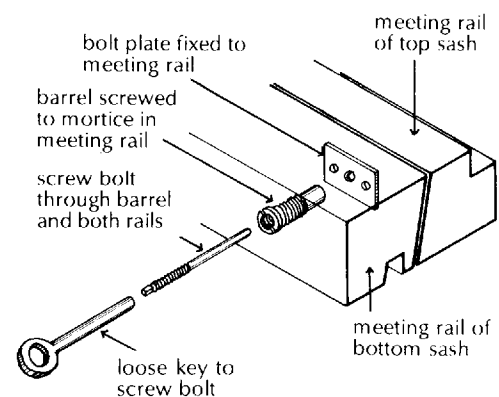
Sash cords are made from twisted or braided flax and cotton cord some 6 mm thick. In time the cord frays and breaks and needs fairly frequent renewal. Cords made from a mixture of nylon fibre and flax have a longer life. Heavy sashes are often hung on brass chains for durability.

The sashes are secured in the closed position by a sash fastener fixed across the meeting rails. Pivoted bar or fitch fasteners are used as illustrated in Fig. 67. Either type of fastener may be fitted with a security lock operated by a loose key. For additional security, screw bolts may be fixed through the meeting rails as illustrated in Fig. 68, or a lock attachment fixed to the sashes, which allows them to be opened sufficient for ventilation and no more, operated by a loose key.

To facilitate opening and closing sashes it is usual to fit sash lifts to the bottom rail of the lower sash and cords and pulleys for raising and lowering the top sash.

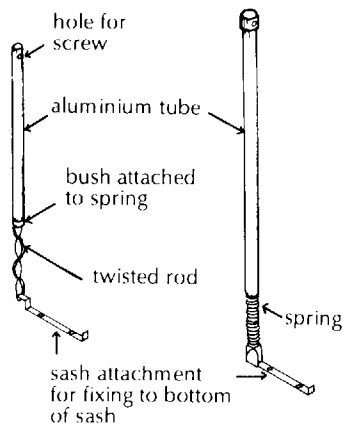


**Fig. 67** Cam (fitch) catch for vertically sliding windows.



**Fig. 68** Dual screw securing bolt for vertically sliding windows.

## Vertically sliding wood sash window with solid frame

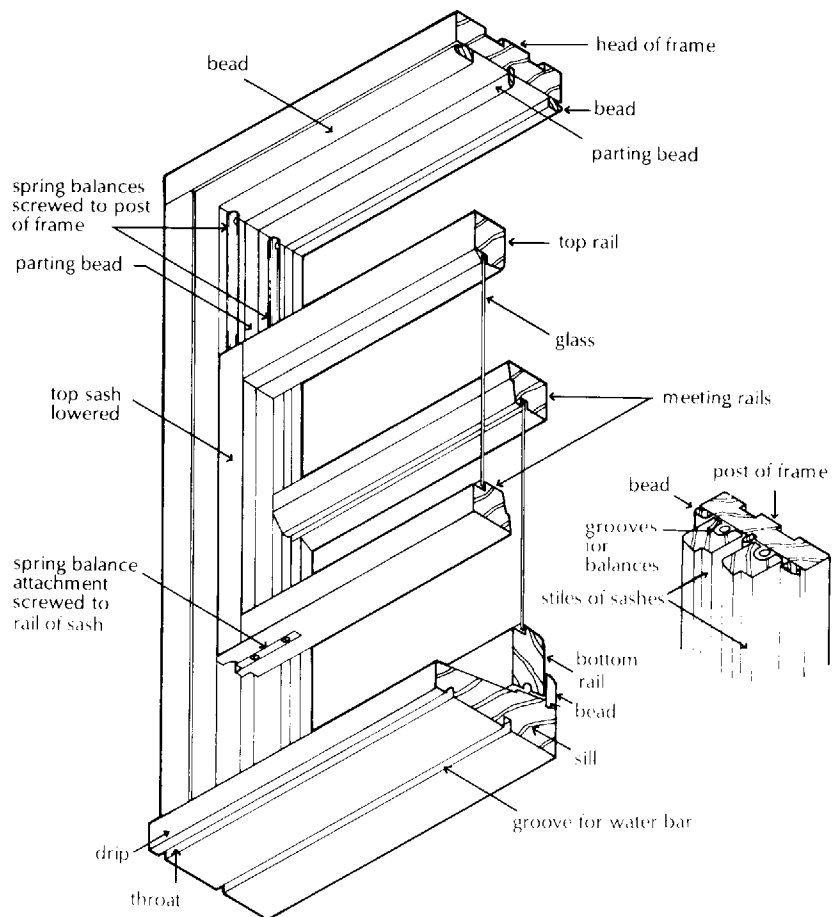


**Fig. 69** Sash balances for vertically sliding windows.

As an alternative to the traditional system of cords, pulleys and weights to hang vertically sliding sashes, spiral sash balances have been used for the past 50 years. The spiral balance consists of a metal tube inside which a spiral spring is fixed at one end. Fixed to the other end of the spring is a metal cap through which a twisted metal bar runs. The tube is fixed to the window frame and the twisted bar to the bottom of the sashes. As the sash is raised or lowered the twisted bar tensions the spring which supports the weight of the sashes, enabling the sashes to be raised or lowered with little effort. Figure 69 shows one of these sash balances.

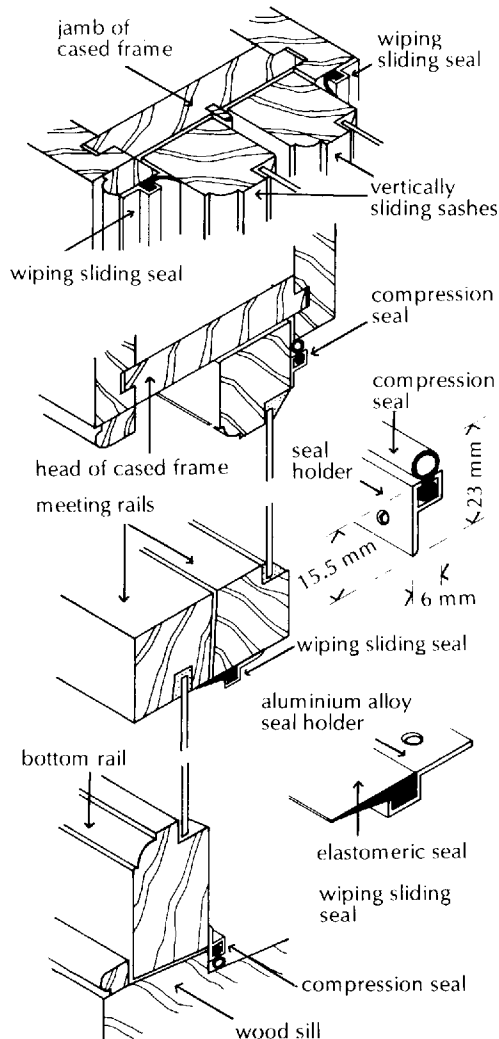
Because of the sash balance there is no need for hollow cased frames to take counterbalances and the frame members can be made of solid sections as illustrated in Fig. 70. The window frame is constructed from four solid rectangular sections of timber, two posts (jambs), head and sill. The posts are joined to the head and sill with combed joints glued and pinned, similar to those described for standard casements. The sashes are similar to those for windows with cased frames, the members being joined with mortice and tenon or combed joints.

A range of vertically sliding wood windows with solid frames cut from standard sections and put together in a range of standard sizes is



**Fig. 70** Vertically sliding sash window with solid frame and balances.

## Weatherstripping



**Fig. 71** Weather seals for vertically sliding wood windows.

## Fixing vertically sliding sash windows

manufactured with the sashes being grooved for and hung on spring balances (Fig. 70).

Vertically sliding sash windows are comparatively simple to weatherstrip to exclude wind and rain. Because of the vertically sliding movement of the sashes a system of wiping, sliding seals is effective for the stiles or sides of the window, with compression seals to the head and sill of the window.

The system illustrated in Fig. 71 employs extruded aluminium alloy holders into which the elastomeric seals fit. The aluminium seal holders are screwed in position.

The wiping, sliding seals are fixed to the staff bead and to the outer lining of the frame so that the flexible seal blades press on to the face of the inner and outer sashes. The wiping sliding action of the seal effectively excludes wind and rain and allows free movement of the sashes.

A special wiping, sliding seal is fixed to the bottom of the outer sash so that when both sashes are closed the flexible seal closes the gap between the meeting rails of the two sashes.

A compression seal is fixed to the bottom rail of the inner sash and the top rail of the outer sash so that when the sashes are closed the seals close the gap between sashes and frames.

A disadvantage of this system is that the small section, aluminium seal holders are visible and that for workmanlike repainting the seals should be removed and refixed after painting.

An alternative system of weatherstripping for vertically sliding windows employs nylon filament and thin plastic blade seals that are housed in plastic holders. To seal the stiles of both sashes to the frame, extruded plastic parting beads are fixed in place of the usual wood parting beads. Plastic seal holders and seals are fixed into grooves in each side of the parting beads to serve as wiping, sliding seals to both sashes.

Plastic seal holders and seals are fitted to grooves in the staff beads to the sides and top and bottom of the frame to act as wiping, sliding seals to the sashes and a seal holder and seal is fitted to the meeting rail of the bottom sash to seal the gap between the sashes.

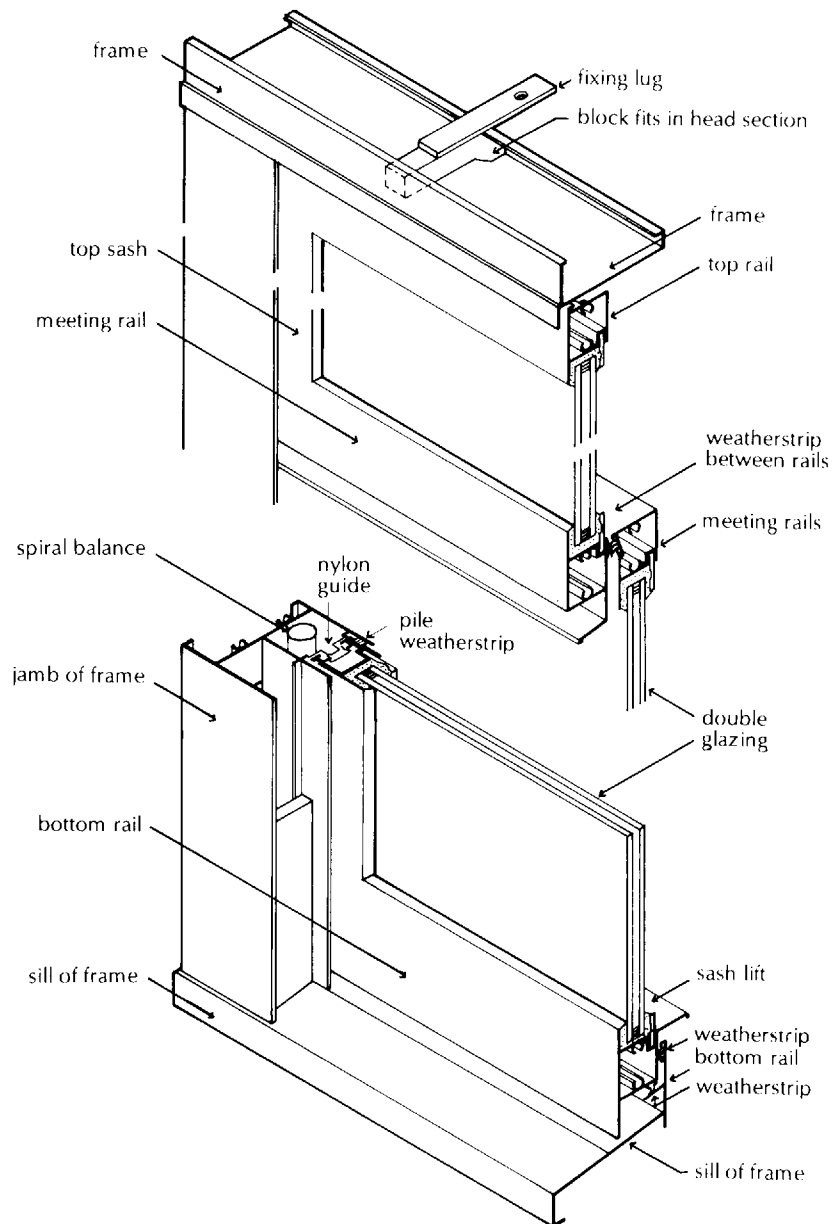
The advantage of these seals is that they are, by and large, invisible.

It used to be common to fix vertically sliding cased frame windows in rebated jambs of solid masonry walls behind a  $\frac{1}{2}$  B deep rebate so that most of the frame was covered and only the sashes showed externally to give the appearance of a window consisting almost entirely of glass. The frame was wedged in position with wood wedges driven between the frame and the brick jambs. This is not a particularly secure method of fixing. Solid frame windows are fixed with lugs or ties screwed to the back of the frame and built into horizontal brick or block joints.

## Perimeter sealing

### Aluminium vertically sliding sash window

These windows are generally built-in and bedded and pointed in mortar.



**Fig. 72** Aluminium vertically sliding sash window.

With the slender sections of extruded aluminium alloy practical for use in the frame and sashes of this type of window, and because the material needs no painting at frequent intervals, aluminium vertically sliding windows have become increasingly popular. The extruded aluminium sections are joined with screw nailed butt joints, mechanical mortice and tenons or mitred and cleated joints with stainless steel screws. The windows are mill finished, anodised or have a stoved powder or acrylic finish.

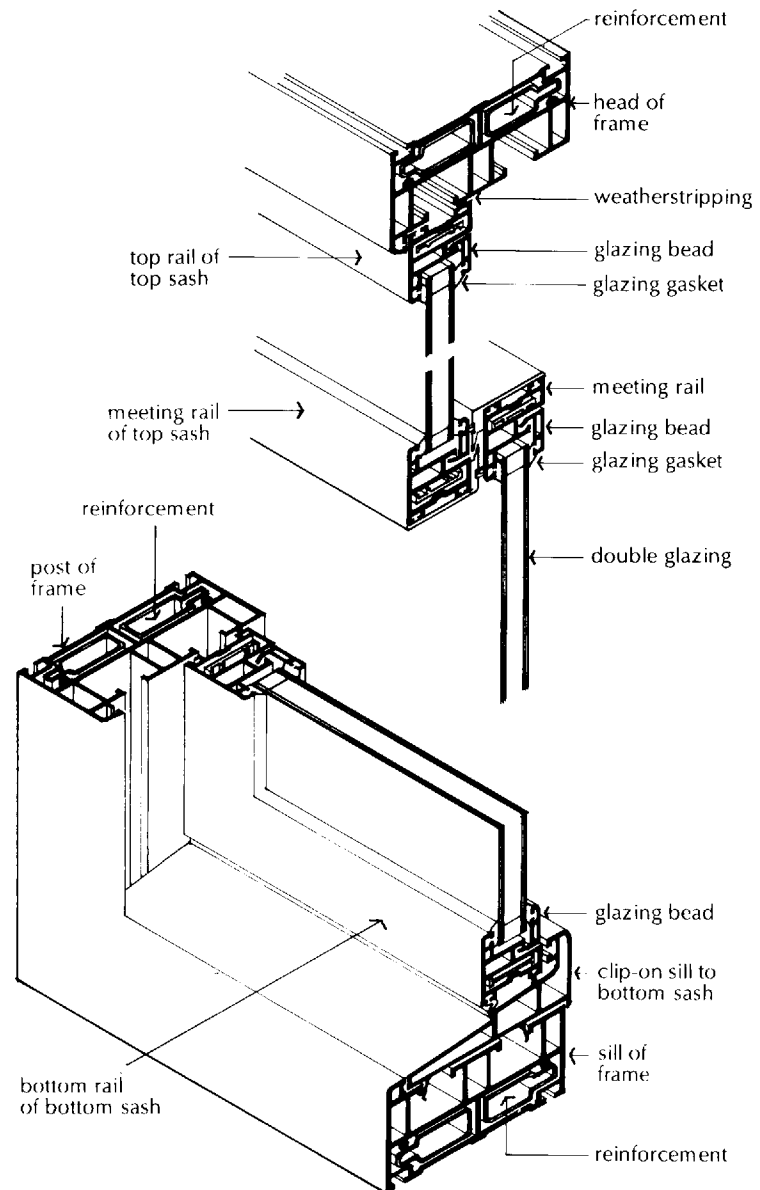
Figure 72 is an illustration of a typical vertically sliding aluminium window. The jamb section houses the spiral spring balances and acts as



a guide for the sashes which have nylon runners and pile weatherstrips. The hollow head section is fitted with pile weatherstrip and a neoprene seal and the sill with weatherstrip. The wider sash sections take either single or double glazing, have integral sash lifts and the meeting rails close to a neoprene seal and are secured with a fitch fastener.

As it is not practical to make this type of window in thermal break construction, these windows are not best suited where warm, moist air may condense to water on the cold metal.

### uPVC vertically sliding sash window



**Fig. 73** uPVC vertically sliding sash window.

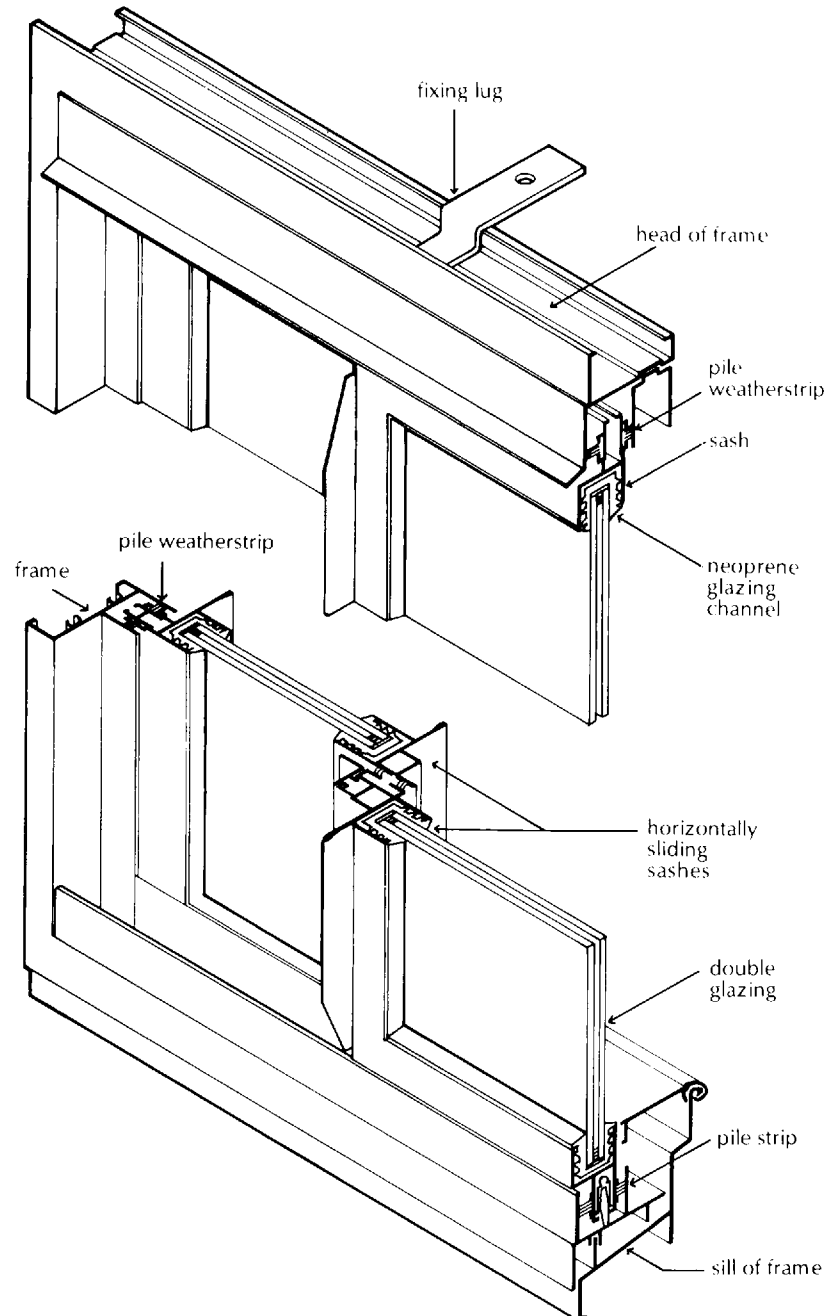
uPVC vertically sliding sash windows have been used as replacement windows for old wood framed windows for the advantage of freedom from maintenance in regular painting and the facility for fitting weatherstripping to grooves formed in the window sections. The vertically sliding, uPVC sash window illustrated in Fig. 73 is framed

with comparatively bulky hollow sections that are reinforced with metal box sections. The hollow box section sash members are designed to take double glazing units.

The sashes are suspended on spiral balances that are housed in hollows in the frame section that are extruded specifically for the purpose.

The comparatively bulky hollow sections of both the frame and sashes are not an entirely satisfactory substitute for the slender sections possible with wood windows.

## Horizontally sliding windows



**Fig. 74** Aluminium horizontally sliding sash window.

The aluminium section horizontally sliding sash window illustrated in Fig. 74 slides on a bottom track with nylon filament, pile weatherstripping acting as weatherseal and as guide to both top and bottom rails and with pile weatherstripping to stiles. To avoid having over bulky sections, this window is not designed as a thermal break window and the frame and sashes will in consequence be a source of condensation in warm moist atmospheres.

As grit may in time collect around the track, it is often somewhat difficult to open these windows which, if forced open or closed, may tend to jamb on the track and so be more difficult to open.

The most common use of this type of window today is as fully glazed horizontally sliding doors, commonly called patio doors.

The aluminium frame and sash sections may be finished with one of the decorative, protective coatings that will not require renewal for many years.

## GLASS

Glass is made by heating soda, lime and silica (sand) to a temperature at which they melt and fuse. Molten glass is either drawn, cast, rolled or run on to a bed of molten tin to form flat glass.

Glass may be classified into three groups:

- (1) Annealed flat glasses.
- (2) Processed flat glasses.
- (3) Miscellaneous glasses.

### (1) Annealed flat glasses

There are two types of annealed flat glass, float or polished plate glass and sheet glass.

### Float or polished plate glass

Clear float or polished plate glass is transparent with surfaces that are flat and parallel so that they provide clear undistorted vision and reflection.

### Float glass

Float glass is made by running molten glass continuously on to a bed of molten tin on which the glass floats and flows until the surfaces are flat and parallel. The continuous ribbon of molten glass is then run into an annealing lehr or chamber in which the temperature is gradually reduced to avoid distortion of the glass. The glass gradually solidifies and the solid glass is cut. The natural thickness of the sheet of glass is 6.5 mm. To produce thinner glass the molten ribbon of glass is cooled and stretched between rollers and to make thicker glass the spread of the molten ribbon is restricted to produce the required thickness.

Float glass has largely replaced sheet and plate glass in this country, and is made in thicknesses of 3, 4, 5, 6, 10, 12, 15, 19 and 25 mm.

**Polished plate glass**

Polished plate glass is made by grinding and polishing both surfaces of rough cast glass. This type of glass has been superseded by float glass.

**Body tinted glass**

Body tinted float glass or polished plate glass is transparent glass in which the whole body of the glass is tinted. This type of glass reduces solar radiation transmission by increased absorption. This material is commonly termed 'solar control glass'. Tints are usually green, grey, blue or bronze and thicknesses 4, 6, 10 and 12 mm.

**Surface modified glass**

Surface modified tinted float glass is transparent glass which during manufacture has a coloured layer of metal ions injected on to the glass. Solar control properties are provided by an increase in reflection and absorption. Thicknesses are 6, 10 and 12 mm.

**Surface coated glass**

Surface coated float glass (reflective float glass) is transparent glass which has a reflective surface layer applied either during or after manufacture. The reflective layer may be on a clear or a body tinted glass. Transmission of solar radiation is reduced by increase in reflection and absorption and the glass has a coloured metallic appearance. Colours are silver, blue and bronze by reflection.

Surface modified and surface coated glasses are solar control glasses that are also referred to as low-emissivity glasses. The effect of the surface coating is to reflect back into the building the long wave energy generated by heating, lighting and occupants, while permitting the transmission of short wave solar energy from outside. This type of glass is designed for use in the inner pane or sheet of glass in sealed double glazing units where the greater inside surface temperature of the glass reduces condensation and the effect of 'cold spot' discomfort.

**Sheet glass****Clear sheet glass**

Clear sheet (drawn sheet) glass is transparent glass manufactured by the flat drawn process in which a continuous sheet is drawn from a bath of molten glass in thicknesses of 3, 4, 5 and 6 mm. The continuous sheet is gradually cooled to minimise distortion and then cut into sheets as it solidifies. The drawn sheet is not exactly flat or uniform in thickness and will cause some distortion of vision.

Sheet glass is no longer manufactured in England.

**Body tinted sheet glass**

Body tinted sheet glass is transparent glass in which the whole body of the glass is tinted to give solar control properties. Tints are usually green, grey or bronze and thicknesses are 3, 4, 5 and 6 mm.

**Cast glass (also known as patterned glass)**

Clear cast glass is translucent glass made by the rolling process. The deeper the pattern the greater the obscuration and diffusion.

**Body tinted glass**

Body tinted glass is similar, with the whole of the glass tinted for solar control and decorative purposes.

**Wired glass**

Wired glass is cast or rolled with wire completely embedded in it. One type of wire is available: Georgian 13 mm square mesh. Cast wired glass is translucent with a cast or patterned surface. Polished wired glass is transparent, through grinding and polishing.

**(2) Processed flat glasses****Toughened glass**

Toughened (tempered) glass is made by heating annealed glass and then rapidly cooling it to cause high compression in the surfaces and compensating tension in the centre of the thickness of the glass. This is a safety glazing material that is less liable to break on impact, and when broken, it fragments into comparatively harmless small pieces.

Clear float, sheet, polished plate and solar control glass may be toughened.

**Laminated glass**

Laminated glass is made of two or more sheets (panes) of glass with an interlayer of reinforcing material between the sheets. The interlayers are permanently bonded to the enclosing sheets of glass. This glass is resistant to impact shock and when broken the reinforcing layer prevents extensive spalling of fragments. The reinforcing interlayer is usually in sheet form and made of polyvinyl butyral. This type of glass is specified as three ply, that is two sheets of glass and one of reinforcement and similarly five ply, with three sheets of glass and two of reinforcement.

This type of glass is often described as safety or security glass.

**Safety glass**

Toughened glass and laminated glass are described as flat safety glass which, on breaking, result in a small clear opening by disintegration into small detached fragments that are neither sharp nor pointed and are unlikely to cause cutting or piercing injuries.

The practical guidance in Approved Document N to the Building Regulations defines critical locations where safety glass should be used. These critical locations are in glazed panels in internal walls and partitions between floor and 800 mm above that level and in glazed doors and door side panels, between floor and 1500 mm above that level.

**Polycarbonate sheet**

Flat plastic sheets made of polycarbonate are manufactured as

transparent, translucent and colour tinted sheets for use as safety glazing. The sheets are 2, 3, 4, 5, 6, 8, 9.5 and 12 mm thick.

The principal characteristic of this material is its high impact resistance to breakage. These sheets do not have the lustrous, fire glazed finish of glass nor are they as resistant to abrasion scratching and defacing. A special abrasion resistant grade is produced.

Polycarbonate sheet, which is about half the weight of a comparable glass sheet, has a high coefficient of thermal expansion. To allow for this, deeper rebates and greater edge clearance are recommended than for glass. To allow for the flexibility of the material and thermal expansion, one of the silicone compounds is recommended for use with solid bedding.

### **(3) Miscellaneous glasses**

In this group of glasses is included double glazing, roof and pavement lens lights, copper lights, leaded lights and hollow glass blocks.

#### **Insulating glass (IG) units, double glazing**

Because of increased demand for thermal comfort in buildings, together with the requirements of the Building Regulations for energy conservation, and the continually increasing cost of fuel, it has become common for some years to fit double glazing to the majority of new and replacement windows. The term double glazing describes the use of two sheets or panes of glass in a window or door. The type of double glazing most commonly used today is the insulating glass unit (IG unit) which comprises two sheets or panes of glass spaced some 6, 10, 12, 16 or 20 mm apart with a perimeter seal so that the air or gas trapped between the glass serves as thermal insulation to reduce transfer of heat through windows.

The U value (thermal transmittance) of a single sheet of 6 mm thick glass is  $5.4 \text{ W/m}^2\text{K}$  and that of an IG unit with two sheets of 6 mm thick glass spaced 12 mm apart is  $3.0 \text{ W/m}^2\text{K}$ .

The advantages of insulating glass (IG) units are that there is some reduction of heat loss or gain as compared to single glazing and that because of the lower U value, that is better insulation against transfer of heat, a larger area of glass in windows may be used in complying with the requirements of the Building Regulations for conservation of energy. There is in addition some small reduction in airborne sound transmission.

#### **Cold spots**

Because of the greater thermal insulation of double glazing as compared to single glazing there may well be a noticeable reduction of 'cold spots' near large areas of glass. 'Cold spots' is the term used to describe the sensation of cold, experienced close to large areas of cold surface in a room, caused by the automatic response of the body in radiating heat towards the cold surface in an attempt to maintain normal skin temperature.

There is reduced condensation of moisture vapour from air because of the higher temperature on the inside of the double glazing as compared to single glazing, particularly in bathrooms and kitchens.

The principal causes of heat loss from rooms are by transfer of heat through glass in windows and doors and by draughts of cold air being forced by pressure through gaps around opening parts of windows and doors, into rooms. Double glazing which will appreciably reduce transfer of heat through glazing will, by itself, effect no reduction in draughts of cold air into rooms. Draught stripping or sealing around opening parts of windows and doors will substantially reduce draughts of cold air irrespective of whether the glazing is single or double.

The considerable initial cost of double glazing and the subsequent cost of replacing double glazed units will at best be covered by savings in fuel costs over very many years, 25 or more. The comparatively small cost of weatherstripping around opening parts of windows and doors provides a much better return on capital than the installation of double glazing. The majority of double glazed windows include effective weatherstripping or seals to all opening windows and doors.

There is no obligation to use double glazing in windows to comply with the requirement in the Building Regulations to conserve fuel and power. Single glazing may be used providing the heat loss through the fabric of the building is limited. Where single glazing is used in windows, particularly those facing the arc of south west, south and south east, account may be taken of solar heat gain to balance the loss through single glazing. Weatherstripping to single glazed windows will appreciably reduce heat loss.

In rooms where hot moist air is common, such as bathrooms and kitchens, it is probably wise to install double glazing to limit condensation of the inside face of windows.

### **Insulating glass (IG) units, sealed double glazing units**

The terms double glazing, sealed double glazing and insulating glass are generally interchangeable. The term double glazing embraces all systems of double glazing whether the glazing is unsealed as in double windows or sealed as in IG units. The term sealed double glazing more precisely describes the system of glazing than the term favoured by the trade, IG units.

Insulating glass units are made up from two sheets (panes or squares) of glass that are hermetically sealed to a continuous spacer in the perimeter of the unit. This spacer maintains the space between the two sheets of glass and supports the sealant. The usual space between the two sheets of glass is 6, 10, 12, 16 or 20 mm.

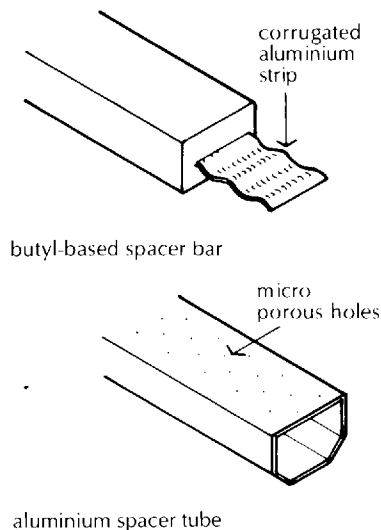
The failure of sealed double glazed units is caused by the entry of moisture vapour into the cavity between the two sheets of glass. This moisture vapour will condense to water on the cavity face of glass in

the IG unit, obscure the glass and the condensate water will run down on to the edge seal. In time this water lying in the cavity will cause further deterioration of the edge seal and the likely entry of further moisture vapour.

The prime cause of the failure of IG units is liquid water both from outside rain and inside condensation that may run down and penetrate faulty edge seals, particularly at corners, and cause deterioration of the adhesive properties of the edge seal.

The durability of a sealed double glazed unit depends on a sound edge seal and sealants around the edges of the unit in the window rebate or sound edge seals and a system of drainage to remove water that may lie in the rebate.

### Space tube or bar



**Fig. 75** Spacer bar and tube.

The spacer which serves to seal and support the adhesive that holds the sheets of glass together is either a hollow aluminium section or a butyl-based bar with an integral aluminium strip, as illustrated in Fig. 75.

Aluminium spacer tubes are either cut to length and connected with metal or nylon corner keys or the space tube is bent to the required shape and the ends of the tube welded together to form a continuous spacer. The usual width of spacer tubes is from 5.5 mm to 19.5 mm to provide a space between sheets of glass from 6 to 20 mm. The narrow widths are made for use in narrow sections of timber and steel windows and the wider for the wider section of uPVC and aluminium windows.

The butyl-based bar, with integral aluminium strip, consists of a preformed section with a corrugated, integral aluminium strip as illustrated in Fig. 75. The aluminium strip serves as reinforcement and in part as a barrier to moisture. A desiccant is embedded in the surface of the bar. The advantage of the bar, commonly known as 'Swiggle strip', is that it is continuous and being self adhesive makes fitting more rapid than using a spacer tube and sealant.

The useful life of a sealed double glazing unit depends on the dehydrated air or gas sealed between the sheets of glass remaining dry. The spacer tube, which serves as a significant barrier to moisture vapour, also serves to support and control the depth of the sealant used.

### Desiccant

To ensure that the air or gas in the sealed cavity between the sheets of glass remains dry, it is necessary to fill the hollow of the spacer tubes with a desiccant which will absorb moisture vapour which might otherwise condense to water on the inside faces of the glass of the unit. The visible face of the spacer tubes is perforated with micro-porous holes to facilitate absorption of moisture vapour by the desiccant. The butyl-based spacer bar has desiccant in the face of the bar.



The sealed space between the two sheets of glass is usually filled with dehydrated air. To provide somewhat better thermal insulation the space may be filled with Argon gas and for better sound insulation it can be filled with SF<sub>6</sub> gas.

## Edge seals

### Single seal

The two edge seals that are used are the single seal and the dual seal.

To hermetically seal the two sheets of glass to the spacer tube it is necessary to run some material around the outside of the spacer tube that will adhere strongly to both the spacer tube and the sheets of glass. To hold the spacer tube in place between the two sheets of glass as an aid to assembly, it is common to use double-sided tape. The sealant in liquid form is then gunned into the space between the two sheets of glass and the spacer tube. The sealants commonly used are polysulphide, polyurethane, silicone, epoxypolysulphide or hot melt butyl. As the double-sided tape does not act as a permanent sealant, this type of seal is described as a single seal (Fig. 76).

### Dual seal

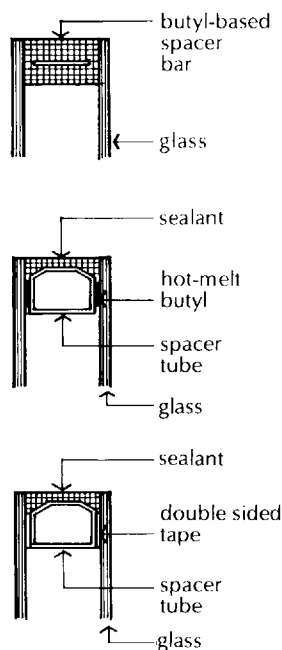


Fig. 76 Edge seals.

As an alternative to the double-sided tape a hot-melt bead of butyl or polyisobutylene is applied to the sides of the spacer on to which the sheets of glass are pressed to keep them in place and then the seal is run in the space between the sheets of glass and the spacer tube. Properly applied the hot-melt butyl will act as a primary seal and the edge sealant as a secondary seal. This dual seal method may provide a longer useful life than the single seal. Figure 76 is an illustration of edge seals to IG units.

As an alternative to hollow spacer tubes an extruded butyl-based bar with integral aluminium strip may be used, as illustrated in Fig. 76. The bar is self adhesive and at once serves to keep the two sheets of glass in place and acts as an edge seal by virtue of the aluminium strip and the butyl bar. This single seal much facilitates the fabrication of IG units and is extensively used.

For appearance, the overall depth of spacer tube and edge sealant and depth of spacer bar should be such that the edges of the face of the spacer that are visible through the glass, the sight faces, should not be visible from outside the glazed unit when it is fixed in position in the window. Likewise for appearance, the sight faces of spacer tubes can be finished, colour coated or anodised.

The useful life of a double glazed unit depends mainly on the integrity of the seal or seals as a barrier to moisture vapour penetrating the space between the sheets of glass, to the extent that the desiccant is unable to absorb most of the moisture vapour that will in consequence condense to water on the cold inside face of the glass. Double seal units generally have a somewhat longer life than single seal units.

It is generally accepted that the useful life of sealed double glazed units is at best up to 20 years. Some assemblies give conditional guarantees of up to 15 years, conditional on workmanship in handling and fixing the units and on the glazing materials used.

## **GLAZING**

The operation of fixing glass in windows, doors and other openings is termed glazing.

The purpose of glazing is to secure glass in position in window frames and sashes and to make a weathertight seal against penetration of rain around the edges of the glass.

The choice of a method of glazing depends on:

- (1) the anticipated structural and thermal movement of the window and
- (2) the degree of exposure of the window to wind and rain.

The common method of glazing for single glazing to softwood and metal frames is putty glazing, and to hardwood, aluminium and uPVC frames is bead glazing with non-setting compounds and tapes for both single and double glazing and gasket glazing for extruded, hollow section aluminium and uPVC frames.

### **Single glazing**

#### **Putty glazing**

Putty is a material that is initially sufficiently plastic to be moulded by hand, spread in the glazing rebate as a bed for glass and finished outside as a weathered front or face putty. The putty sets or hardens over the course of a few days to secure the glass in position and serve as an effective seal against rainwater penetration.

Glazing with putty, which dries and sets to a hard finish, is used to secure glass in wood or steel frames where there is little structural and thermal movement. Putty is not used on aluminium or plastic frames where the larger structural and thermal movement of these materials might cause the putty to crack, lose adhesion and allow rain to penetrate.

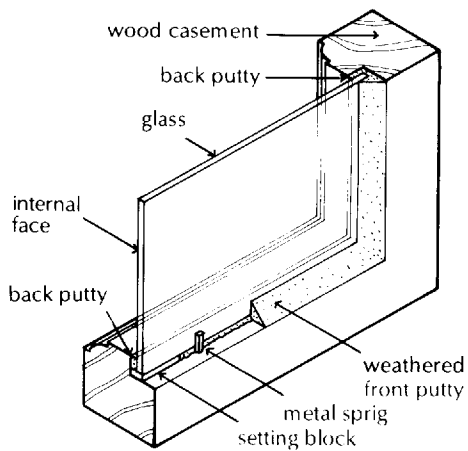
#### **Linseed oil putty**

Linseed oil putty, which is used for glazing to softwood and absorbent hardwood frames, adheres to both glass and wood and hardens by absorption of some of the oil into the wood and by oxidation. To prevent too great an absorption, softwood windows should be primed before glazing.

Putty is spread by hand in the glazing rebate.

#### **Setting and location blocks**

To provide an edge clearance of 2 mm between the edges of the glass and the rebate, to allow for variations in the sash and in the glass and to facilitate setting the glass in place, setting and location blocks are



**Fig. 77** Putty glazing to wood sash.

used. Setting and location blocks, which are of PVC, hammered lead, hard nylon or hardwood are 2 mm thick and 150 mm long. Setting blocks are pushed into the soft rebate putty in the bottom edge rebate to support the glass and the location blocks into both side rebates to centre the glass.

Figure 77 is an illustration of linseed oil putty glazing to a softwood sash.

The glass, which has been accurately cut to provide an edge clearance, is placed on the setting blocks and pushed firmly into the putty to squeeze surplus putty between the glass and the upstand of the rebate as a back putty bed 1.5 mm thick.

Glass is then secured in position, until the putty has hardened, with metal sprigs that are tapped into the rebate at not more than 300 mm spacing. Sprigs are small, cut, headless nails.

Additional putty is then spread by hand in the glazing rebate around the edges of the glass and finished with a putty knife at an angle from the edge of the glazing rebate up to about 2 mm below the sight line as a seal against rain penetration. Surplus back putty is stripped and the back putty is finished at an angle up to the glass to shed any condensation water from the inside face of the glass.

The finished putty should be left to harden for at least 7 days and then painted with the usual undercoat and finish coats of paint to prevent further hardening of the putty. The painted surface should be finished on to the glass as a seal against rain penetration behind the putty.

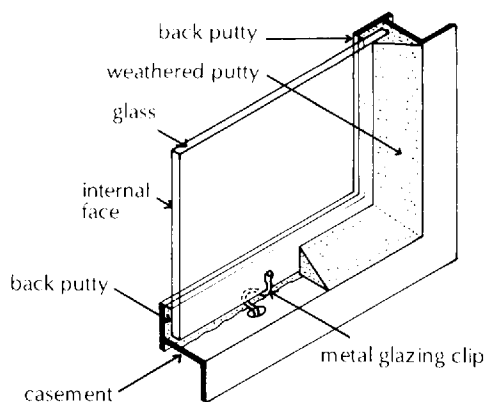
## Metal casement putty

Metal casement putty is designed specifically for use on non-porous surfaces such as galvanised steel frames, sealed timber and sealed concrete with or without glazing beads. It is made from a blend of vegetable oils selected to adhere to and set on non-porous surfaces. It is not suitable for glazing to aluminium, stainless steel, bronze or plastic finishes.

This putty hardens and sets and will accommodate the relatively small amount of movement that occurs in steel frames due to temperature change. The putty hardens within 7 to 14 days and should then be painted to prevent further hardening.

Where the galvanised surface of steel frames has been weathered, exposed to atmosphere or treated, the metal casement putty may be applied directly to the frame.

Putty is spread by hand in the glazing rebate. Setting and location blocks are pressed into the putty in the bed of the glazing rebate to maintain the edge clearance of 2 mm around the glass. The glass, which has been accurately cut with a 2 mm edge clearance, is then



**Fig. 78** Putty glazing to metal sash.

## Glazing with beads

As an alternative to putty glazing for single glazing, which may not always provide a neat finish, bead glazing may be used, where a bead secures the glass in place.

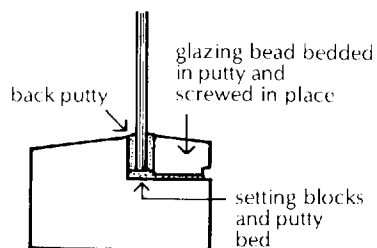
The choice of internal or external fixing of glazing beads depends on the material of the bead, the ease of access for reglazing, appearance and security.

For durability inside glazing is preferable, particularly when softwood beads are used because the joints between the bead, the glass and the frame are vulnerable to the penetration of rain.

For access for reglazing inside beads are best as they are also for security to ground floor windows.

For appearance sake, where stained, oiled or varnished hardwood is used as a decorative and protective finish, glazing beads of the same material and finish are used internally.

## Glazing with putty and beads



**Fig. 79** Glazing with putty and beads.

Glazing with putty and beads may be used for softwood, absorbent hardwood and galvanised steel frames. In sheltered positions the beads may be external, for other exposures they should be internal.

Sufficient putty is spread all round the rebate to provide adequate back putty. Setting blocks are pressed into the putty in the platform rebate and location blocks as necessary. The glass is placed on the setting blocks and pressed firmly into the rebate so that putty 1.5 mm thick is squeezed between the glass and the back of the rebate as back putty bedding as illustrated in Fig. 79.

For fixing externally beads should be bedded with putty against the glass and to the bed of the rebate. The beads are pressed firmly against the glass and then secured with pins or screws. Where beads are fixed internally it is not usual to bed them in putty. Back and front

putty beds are trimmed and finished with a slope up to the glass. The exposed putty should be painted some 7 to 14 days after glazing.

For putty glazing to non-absorbent hardwood and galvanised steel frames metal glazing putty is used.

## Glazing with tape and beads

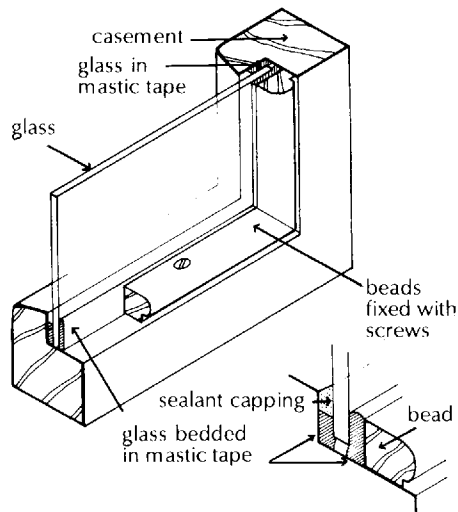


Fig. 80 Glazing to wood with beads.

As an alternative to putty glazing for large squares of glass for both wood and galvanised steel frames, load bearing mastic tape and a sealant may be used.

Load bearing mastic tape is made from compressed fabric and butyl in various widths and thicknesses. The tape which is used as a bedding for glass will serve as a sealant to exclude rain when it is adequately compressed. It is comparatively easy to use and often preferred to putty.

A strip of the mastic tape is pressed into position all round the rebate upstand so that it finishes some 3 to 6 mm below the sight line and setting blocks are placed in the rebate base. Glass is placed on the setting blocks and firmly pressed into the rebate to compress the tape to the rebate upstand. Location blocks are fixed in the side edge clearances to centre the glass.

A second strip of mastic tape is fixed around the outside edges of the glass and the internal glazing beads are fitted in place, pressed firmly against the mastic tape and screwed into position. A sealant is run, by gun, into the edges of the outside of the glass and finished with a smooth chamfer or slope to shed water as illustrated in Fig. 80.

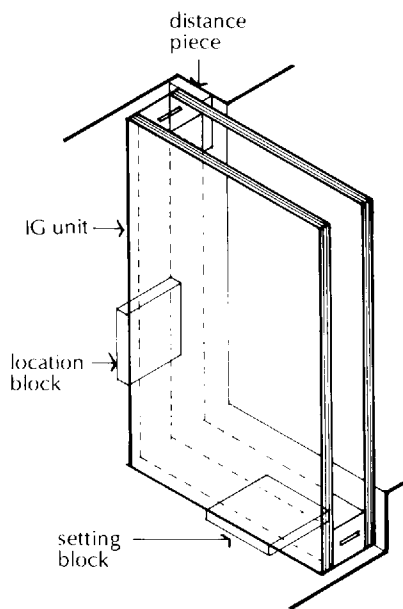
## Glazing IG units

Insulating glass units are hermetically sealed and subject, therefore, to continuous flexing due to changes in atmosphere and temperature. Glazing materials that are used must allow for thermal and structural movement of both the IG unit and the window framing. The glazing method used should allow for movement and prevent water penetrating to the edges of the IG unit.

## Setting and location blocks

To accommodate movement between glass and window frames, casements or sashes, due to different thermal and mechanical movements, a minimum clearance must be allowed all round IG units of from 3 mm for glass up to 2 m wide to 5 mm for glass over 2 m wide at sides and top of unit, and 6 mm at sill level.

Setting blocks and location blocks should be of some resilient, non-absorbent material such as sealed teak or mahogany, hammered lead, extruded uPVC, plasticised PVC or neoprene. The width of setting



**Fig. 81** Blocks for IG units.

blocks should be equal to the thickness of the IG unit plus the backface clearance and at least 25 mm long. Location blocks should be 3 mm wider than the IG unit and at least 25 mm long.

Distance pieces are used to prevent displacement of glazing compounds or sealants by wind pressure on the glass, by retaining the IG unit firmly in the window. Distance pieces should be used except where load bearing tapes or putty are used for stepped units. Distance pieces should be the same thickness as face clearance and made of a resilient, non-absorbent material similar to that for setting blocks. Figure 81 is an illustration of the use of these blocks.

Sight size is the actual size of the opening that admits daylight and the sight line is the perimeter of the sight size. The sight line is determined by the edges of the frame, casement or sash and the exposed edge of the glazing material. The practice is to fix or apply glazing material so that the sight line on the inside of the glass coincides with that on the outside and just above the exposed face of the spacer tube or bar in the IG units, for appearance sake.

## Factory glazing, site glazing

Insulating glass units may be delivered to site factory glazed to windows. The advantage of factory glazing is that the operation of glazing can be carried out under cover in conditions most suited to making a good job. The disadvantage of factory glazing is the possibility of damage to the glazed window in transit and through handling on site. The best conditions for glazing are clean, dry surfaces to which bedding and sealant materials can adhere. Because such conditions are rare on most building sites, factory glazing should have advantage over the other option, site glazing.

## Glazing methods

The two systems of glazing used for insulating glass (IG) units are solid bedding and drained methods.

### Solid bedding

The solid bedding method depends on the use of mastic bedding materials around the edges of the IG unit, inside the glazing rebate, with sealants to prevent the penetration of water to the edges of the unit. This method of bedding is most suited to window frames with plain, square sections and rebates such as wood or steel windows into which the unit may be bedded and secured with beads.

### Drained glazing

The drained method of glazing is designed to encourage water, that may have penetrated the glazing rebate around the edge of the IG unit, to drain to the outside. This method of glazing, which is particularly suited for use with the systems of gasket glazing commonly used with extruded, hollow sections of uPVC and

aluminium windows, may be employed with plain section wood, steel, aluminium and uPVC windows.

Whichever method is used, the first defence against penetration of water to the edge seal of the IG units is the mastic or rubberised edge seals to glass which should at once accommodate movement and act as a seal against water. Drainage is a back up to drain any water that has penetrated. To be effective the drainage system should at once be adequate to drain water, be protected against wind-blown rain and remain clear of obstruction during the useful life of the window, conditions that may be difficult to achieve satisfactorily.

## Solid bedding

### Beads with non-setting compound

Solid bedding depends on the use of solid beads, firmly fixed to the frame, to contain or compress the mastic or plastic bedding material around the edges of the IG units, to prevent the penetration of water to the IG unit edge seal.

This is the most straightforward method of bedding IG units in window frames of wood or metal, where one material is used both as bedding and sealant.

The bedding-sealant materials that may be used are non-setting compounds of synthetic rubber, oils and fillers or low permeability one- or two-part curing sealants such as polysulphide, silicone or urethane base.

The clean rebates and wood beads are first primed or sealed. A generous fillet of bedding material is spread in the rebate into which setting blocks and distance pieces are pressed. The distance pieces are necessary to maintain the correct thickness of bedding, behind the glass, against wind pressure on the glass. The glass is then placed on the setting blocks and pressed firmly into the rebate against the distance pieces to provide a 3 mm thick back bedding.

Location blocks are fixed in the side edge clearance. Bedding material is spread around the edges of the glass to fill the edge clearance gaps around the IG unit. A substantial fillet of bedding material is spread in the glazing rebate. The wood beads are bedded in position and pressed firmly into the bedding material so that there is 3 mm of bedding between the glass and the bead and a thin bedding below the bead. The wood beads are secured in place with screws at maximum 200 mm centres and no more than 75 mm from corners.

The bedding inside and out is trimmed and finished with a smooth chamfer or slope to shed water as illustrated in Fig. 82.

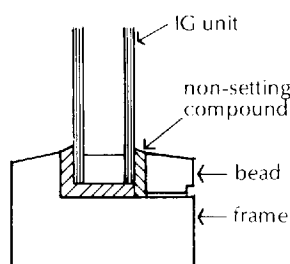
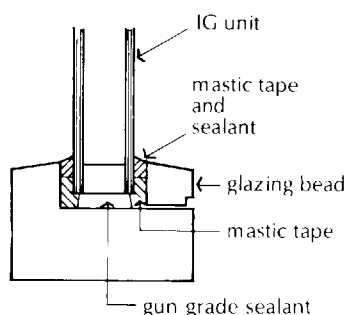


Fig. 82 Solid bedding glazing.

### Beads with load-bearing tape and sealant

An alternative method of solid bedding for IG units glazed to wood and metal frames uses load-bearing mastic tape or cellular, adhesive



**Fig. 83** Solid bedding glazing.

sections as face bedding and non-setting sealant as capping and bed for units.

Preformed load-bearing mastic tape is made from a fabric base, saturated in butyl (synthetic rubber) or polyisobutylene polymers in various widths and thicknesses. The tape is compressed during manufacture so that it has adequate load bearing capacity as bedding for glass, to resist wind pressure on the unit.

A strip of mastic tape is fixed to the rebate upstand with its top edge about 6 mm below the sight line and setting blocks are placed in the rebate platform to support the IG unit. The IG unit is placed on the setting blocks and pressed firmly into the rebate up to the mastic tape in the upstand of the rebate.

One-part or two-part sealant of polysulphide, silicone or urethane is run into the clearance gap between the lower edge of the IG unit and the rebate as bedding and as a thin bed for the glazing bead.

A strip of load-bearing tape is run around the outside edge of the unit or the back face of the bead so that its top edge finishes some 6 mm below the sight line. The beads are fixed in place and pressed in firmly to compress the tape and bed the wood beads, which are screwed in place at a maximum of 200 mm and no more than 75 mm from corners.

Sealant capping is run around both sides of the glass and finished with a slope or chamfer as illustrated in Fig. 83.

Various combinations of load-bearing tapes and sealants, non-setting compounds and sealants and sealants by themselves may be used as bedding and sealants for solid bedding glazing of IG units, depending on the nature of the materials of the window framing and convenience in the operation of glazing.

## Drained glazing

The drained method of glazing for IG units is designed to remove any water that has penetrated to the bottom rebate by drainage and to some extent by ventilation. Any water that lies for some time in the bottom rebate will adversely affect the adhesive edge seal to IG units.

## Insert gasket glazing

The majority of extruded, hollow section uPVC and aluminium window frames employ gasket glazing systems. Gaskets are pre-formed sections of synthetic rubber that are shaped for insertion between the nibs around a groove in the glazing bead or the frame of the window and so positioned that the blades or bearing edges of the gasket make firm contact with glass faces as illustrated in Fig. 84, to exclude rain and allow for some structural and thermal movement between frame and IG unit.

Gaskets should be inserted in the nibs in grooves provided in one



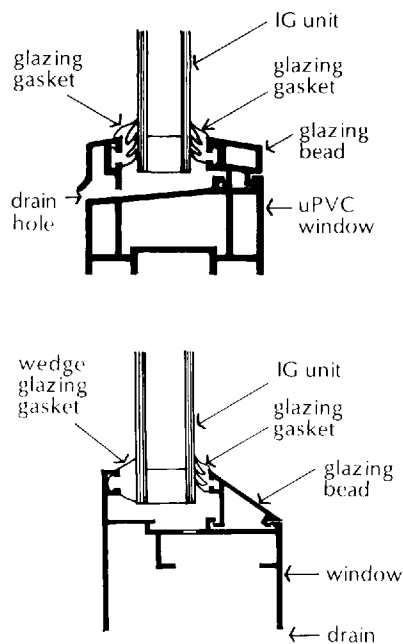


Fig. 84 Drained glazing.

### Drainage to square section frames

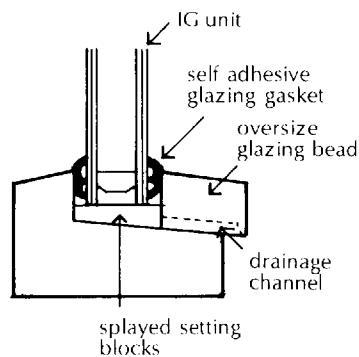


Fig. 85 Drained glazing.

length. The gaskets are nicked at corners to ease bending and the joint of the gasket ends should be at the centre of the top of the frame.

Because there is some possibility that wind-driven rain may penetrate the junction of gasket and glass, it is common practice to provide a means of removing any water that has run to the bottom glazing rebate.

Plastic blocks are placed on the platforms of the bottom rebate to support the IG unit. The unit is placed on the setting block and pressed on to the inside gaskets and centred by means of location blocks wedged between the side of the IG unit and frame. The beads with gasket in place are then fixed in position on the outside of the frame in clip-in nibs around grooves or by means of screws, so that the gaskets bear firmly on the glass face.

The void spaces between the edges of the IG unit and the frame are left unobstructed so that any water that penetrates outside gaskets can run down to the bottom rebate and out through drainage holes as illustrated in Fig. 84.

The points in this system of glazing that are most vulnerable to rain penetration are the corners of the window where the outside beads are mitred and butt together.

As an alternative to solid bedding for square section wood and metal frames, systems of face bedding or gasket glazing with drainage to the bottom rebate may be used. For drainage the bottom rebate platform should be cut to slope out at an angle  $10^\circ$  to the horizontal.

For face bedding systems tapered setting blocks are placed in position. Load-bearing mastic tape is fixed to the upstand of the rebate, finishing about 6 mm below the sight line. The IG unit is placed on the setting blocks and pressed firmly on to the mastic tape. Mastic tape is fixed to the lower edges of the outside glass or the glazing beads, finishing about 6 mm below the sight line, and the beads are placed in position and pressed firmly up to the edge tape and the beads secured with screws.

A capping of silicone or other sealant is run into the 6 mm space around both inside and outside glass and finished with a slope or chamfer to shed water.

Any water that penetrates the outer bedding and seal will drain out through 10 mm diameter holes cut in the underside of the wider bottom bead, as illustrated in Fig. 85.

As an alternative to face bedding and sealant, profiled, closed cell, synthetic sections or strips, with self adhesive backing, may be used.

The self adhesive strip is fixed to the upstand of the rebate. Setting blocks are placed in position and the IG unit is placed on the setting blocks and pressed up to the back face of the rebate. Self adhesive tape is fixed to the glazing beads which are pressed up to the IG unit

## Double glazing for sound insulation

and the beads are screwed into position. Drainage of water is through holes in the underside of the oversize bottom bead.

A major part of the penetration of sound through windows is transmitted as airborne sound through gaps between opening sashes and frames of windows.

Appreciable reduction of sound transmission through windows can be achieved by fitting weatherseals around all opening parts. Reduction of sound by weatherstripping can be appreciated by comparing sound penetration through an open and a closed weatherstripped window facing a busy urban road.

Where indoor quiet is at a premium and windows are necessary for daylight, double glazing with a comparatively wide air space between sheets of glass may be used for additional reduction of sound transmission. In effect two windows are built into the opening, separated and not connected, by some 150 mm between the two sheets of glass as illustrated in Fig. 17.

The outer window consists of a fixed light and the inner window is hinged to open in for the purpose of cleaning glass facing the cavity. This opening light is fitted with weatherstripping. The inside of the cavity is lined with an acoustic lining made of a material that will absorb some of the energy causing the air movement that causes sound. By fixing the two windows separately, vibrations of the outer sheet of glass, caused by airborne sound, will be reduced by the still air in the wide cavity and so have less effect on the inner sheet of glass.

A disadvantage of this sound insulation arrangement is that the wide air space will be less effective, as thermal insulation, than a narrow cavity up to 20 mm would be. The reason for this is that the air inside the wide cavity has more volume in which convection currents can circulate and so transmit more heat between the two sheets of glass and so increase heat loss, than a narrow cavity of say 12 mm would.

## WINDOW SILLS

It is good practice to set the outside face of windows back from the outside face of the wall in which they are set, so that the reveals of the opening give some protection against driving rain. Wind-driven rain, which will run down the impermeable surface of the window glass to the bottom of the window, should be run out from the window by some form of sill. The function of an external sill is to conduct the water that runs down from the windows away from the window, and to cover the wall below the window and exclude rain from the wall. The material from which the sill is made should be sufficiently impermeable and durable to perform this function during the life of the building.

External window sills are formed either as an integral part of the

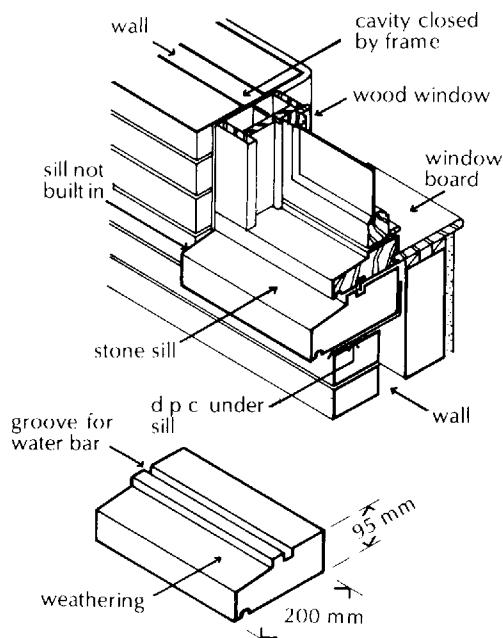
window frame, as an attachment to the underside of the window, or as a sub-sill, which is in effect a part of the wall designed to serve as a sill. Most materials used for external sills are pre-formed so that the dimensions of the sill determine the position of the window in relation to the face of the wall. As a component part of a wall external sills should serve to exclude wind and rain and provide adequate thermal insulation to the extent that the sill does not act as a thermal bridge to heat transfer.

The internal sill of a window serves the purpose of a finish to cover the wall below the window inside the building, and as a stop for wall plaster. The material used for internal sills should be easy to clean and materials commonly used are painted softwood, plastic, metal and clay tiles.

## External sub-sills

These sills are constructed as a capping to a solid wall below windows, as a weathering to run water away from the window, to protect the wall below and as a finish between the wall and the window. The materials used are natural stone, cast stone, concrete, tile and brick. Natural sedimentary igneous and metamorphic stone sills are less used than cast stone, concrete, tile and brick sills due to the scarcity and cost of the material. Slate sills, which are readily available but comparatively expensive, are used to some extent.

## Natural stone sills



**Fig. 86** Natural stone or cast stone sill for wood window.

Natural stone sills of sedimentary or igneous stone such as limestone, sandstone or granite (see Volume 1) are specially cut to section to provide a weathered surface, a groove for water bar and overhanging drip edge as illustrated in Fig. 86.

The top surface of the sill is finished flat, as a bed for the window sill. A groove is cut in the top of the sill to take a metal water bar that is set in mastic in the stone sill and the underside of the wood window sill. The water bar acts as a check against wind-driven rainwater that might otherwise penetrate between the stone sub-sill and the wood window sill.

A shallow sinking is cut in the top of the sill down to a weathered face that slopes out to shed water. The shallow sinking acts as a check against wind-driven rain being blown up the weathered sill face. A shallow groove is cut near the outside edge of the underside of the sill to form a drip edge to encourage rainwater to run off.

The sub-sill shown in Fig. 86 is cut to length to fit between the jambs of the window opening. The ends of the sill are bedded and pointed in mortar. The mortar joint between the end of the sub-sill and brick may not be entirely watertight, particularly in exposed positions. It is for this reason that the under-sill damp proof course

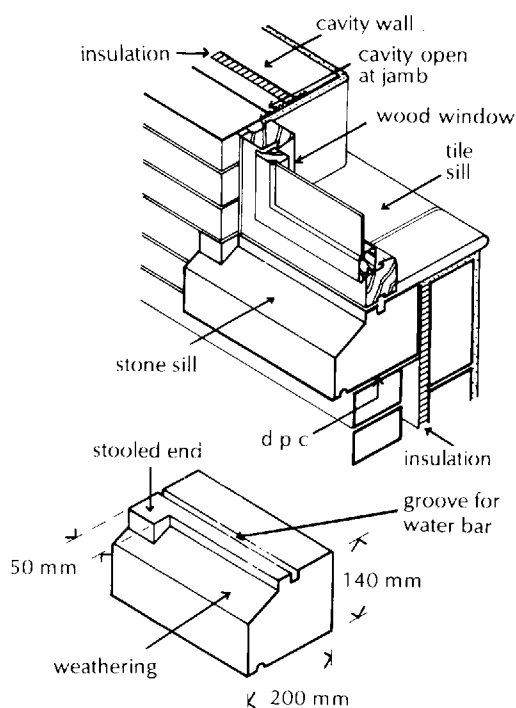


Fig. 87 Natural stone or cast stone sill.

### Reconstructed and precast concrete sills

(dpc) is extended half a brick beyond the jambs as shown in Fig. 88. The projection of the outer face of the sub-sill beyond the face of the wall below is usually about 30 mm.

As an alternative to plain end sills, that fit between the jambs of window openings, the ends of a sill may be stooped for building into the jambs of openings as illustrated in Fig. 87.

A stooped end is cut on each end of the sill as a bearing for the brickwork or stonework that is built up in the jambs of the opening. To allow for the necessary depth of stone required to cut weathering, sinking and a substantial thickness of stone at the overhang, sills with stooped ends should be two courses of brickwork deep to avoid untidy cutting of bricks.

Stooped ends to stone sills provide a solid bearing to walling at jambs and a weatherseal against water penetrating between sill and jamb. Sills with stooped ends are commonly used with stone walling so that the sill may bond in with stonework.

Stone sub-sills are bedded in mortar on the under-sill dpc, bearing on the outer brick leaf of the cavity wall. As the sill does not extend to the insulating block inner skin of the cavity wall or across cavity insulation, it will not act as a thermal bridge (see Volume 1).

Reconstructed stone is made from a mix of natural stone, crushed to a maximum size of 6 mm, cement and just sufficient water for moulding and setting. The mix is cast inside timber moulds formed to the shape of a weathered stone sill such as that illustrated in Fig. 87. The reconstructed stone sill may be made with either ordinary or white cement to produce a product that closely resembles the texture and colour of the natural stone from which it is made. Well made reconstructed stone may be indistinguishable from the natural material from which it is made.

Precast concrete sills are made from ordinary natural aggregate concrete and cement which is cast and compacted by vibration in moulds, with either a natural concrete finish or an integral cast finish of crushed natural stone and cement as facing to exposed faces.

Precast concrete sills, which may initially resemble the colour and texture of natural stone, do not weather like natural stone and are liable to irregular and unsightly stains in a few years.

Sub-sills of stone, reconstructed stone and precast concrete with stooped ends built in to the surrounding walling should be hollow bedded. The term 'hollow bedded' describes the operation of

laying a few courses of the stone or brickwork below the sill in dry sand.

The purpose of this operation is to make allowance for the likelihood of the more heavily loaded walling at jambs of openings sinking somewhat more than the less heavily loaded walls under sills. If the sill had been solidly bedded in mortar the sinking of walling at jambs might cause the sill to break its back and crack at about the centre of the sill length. On completion of the walling, the stones or bricks below the sill which were hollow bedded in sand are taken out and laid in mortar up to the underside of the sill.

### Damp proof course below sills

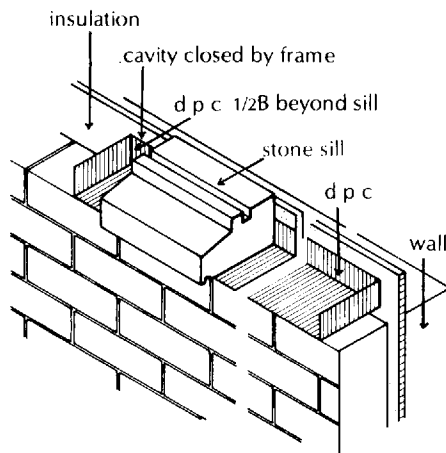


Fig. 88 Under-sill dpc.

Sub-sills of stone, reconstructed stone and precast concrete with square ends and sills of small units such as brick and tile may not be entirely effective in excluding rain that may penetrate joints in and at the ends of sills to the wall below, particularly in exposed positions. It is practice, therefore, to build in a sub-sill dpc as illustrated in Fig. 88.

The material most used as dpc is sheet lead which can be worked and shaped to the required shape and size without damage and which will prevent penetration of water to the walling below the sill. A sheet of Code 4 or 5 lead is shaped to lie as a bed under stone sills with upstand ends behind and to the ends of the sill.

Where the stone sill has plain ends for building-in between jambs of opening the lead under-sill dpc is extended  $\frac{1}{2} B$  beyond the sill ends as protection against entry of water through the mortar joint between sill ends and jamb walling to the walling below.

Other materials that may be used instead of lead sheet are bitumen felt and plastic sheet. Both of these materials are difficult to apply in one sheet to the bed and up the back and ends of stone sub-sills.

### Slate sills

Slate sills are cut from some fine-grained natural slate and finished in a range of standard and purpose-made sections to suit either timber or metal windows. The slate is finished with a sawn, sanded or fine-rubbed finish. The natural colour of the slate varies from light grey and green to blue and black. This dense, durable material is impermeable to water, requires no maintenance, is a poor thermal insulator and being brittle may crack due to movement of the building fabric. These sills should be cut and finished in one length to avoid the difficulty of making a weathertight joint in the material, a limitation

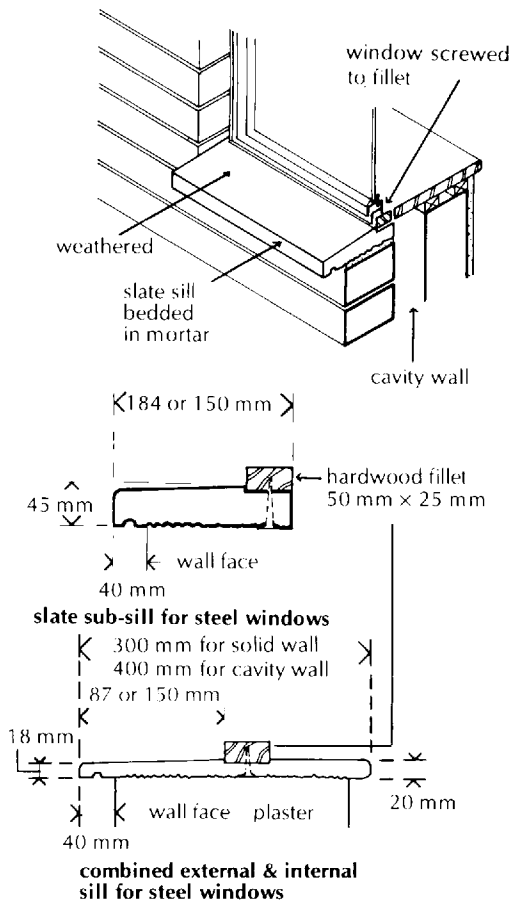


Fig. 89 Slate sills for steel windows.

which restricts their use to comparatively narrow windows unless a generous thickness of slate is used.

The two standard sections illustrated in Fig. 89 are for use with standard steel windows which are screwed to the fillet fixed to the sill. Sills for use with wood windows are finished with a groove for a water bar. These sills are bedded in mortar on the wall below the window with the drip edge projected some 38 mm beyond the face of the wall.

The sill shown in Fig. 89 is cut in one length to fit between the jambs of the window opening, with the vertical joint between the end of the sill and the jamb filled with mortar and pointed with non-setting mastic compound. This is a satisfactory joint for normal exposure to driving rain. In positions of severe exposure it is wise to incorporate a lead dpc tray under the sill, cut and shaped to extend some  $\frac{1}{2}$  B each side of the opening to exclude water.

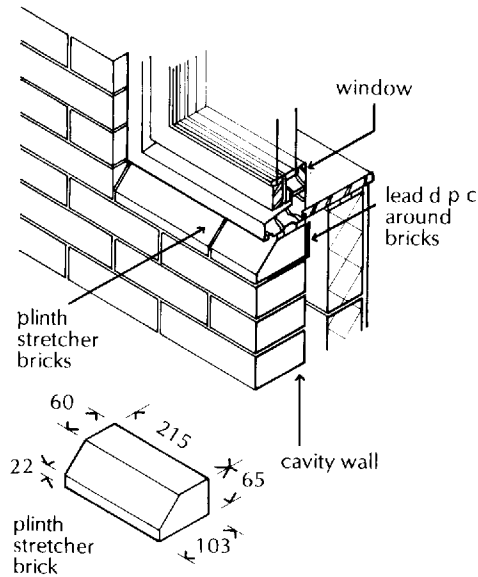
These sills may be cut and finished with stooled ends for building into the jambs of openings. This costly end detail does not provide a satisfactory finish unless the sill is a full brick thickness, otherwise untidy cutting of brickwork is necessary. Where the ends of these comparatively thin sills are built in, differential settlement between the more heavily loaded walls at the jambs and the less heavily loaded walling under the window may cause the sill to crack.

The combined external and internal sill shown in Fig. 89 acts as a cold bridge across the thickness of the wall and will encourage condensation on the top of the internal sill. Because it is comparatively thin, the sill is liable to crack due to handling and slight movements in the wall and is used for only narrow window openings.

## Brick sills

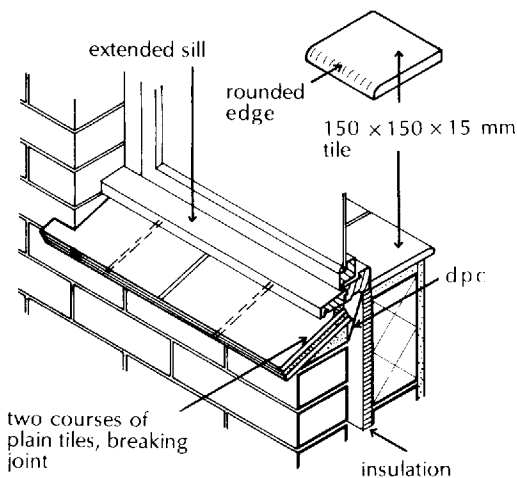
A common method of forming a sub-sill to window openings in walls of fairface brickwork is with a course of bricks laid on edge or a course of bricks specially made for the purpose. Whichever method is used the bricks should be sufficiently dense and weather resistant to stand the appreciable volume of rainwater that will run off the impermeable surface of the glass above. It may not be sufficient to use the bricks that are used for the surrounding brickwork.

The reason for this is that brickwork resists the penetration of water to the inside face of a wall by absorbing a considerable amount of the rain that falls, which evaporates to air during dry spells, without suffering damage. The bricks in sills suffer greater saturation



**Fig. 90** Brick sill.

### Tile sub-sill



**Fig. 91** Plain tile sill.

### Metal sills

by rain and may, unless they are dense, suffer damage by frost action due to the expansion of the water in the bricks. For this reason, dense, well burnt bricks such as semi-engineering or engineering bricks are used in sills.

Standard size bricks are laid on edge as sills with one stretcher face and one header face exposed. The stretcher face top surface of the sill may be laid to a slight fall to shed water. The bricks are laid and pointed in cement mortar with the back edge of the bricks at least 30 mm behind the window sill edge and finished either flush with or projecting from the wall face as a drip edge.

The special plinth bricks, illustrated in Fig. 90, are made from dense clay and formed with a sloping weather face to shed rain water. The bricks are laid on bed in cement mortar with the back face of the bricks set well back under the window sill so that there is a generous overhang of the drip edge of the wood sill above. A lead dpc is bedded below the sill bricks, turned up behind them and continued  $\frac{1}{2}$  B beyond the jambs of the window opening.

As a comparatively cheap form of sub-sill, two courses of clay or concrete plain tiles are laid, breaking joint, in cement mortar. The majority of clay tiles which absorb water fairly readily, should be laid at a slope of 40 to 45° to the horizontal if they are to avoid suffering frost damage. Such a steep slope for a tile sill would be too great to ensure secure bedding. Machine pressed or concrete plain tiles, which may resist the likelihood of frost damage at a slope of 30° are therefore used.

The tiles may be laid with their long axis parallel to the wall face to avoid cutting tiles or with their long axis at right angles to the wall and cut as necessary to suit the position of the window. The tiles may be finished square to the jambs of the window opening or notched around the angle of the jambs for appearance sake, as illustrated in Fig. 91.

The tiles should be laid with their back edge well back under the window sill, so that there is a generous overhang of the window sill, and project out beyond the wall face about 38 mm as a drip edge. A lead or bitumen felt dpc should be bedded below the tile sill and bedding.

Many consider this form of sub-sill to be an untidy, unattractive finish to the bottom of a window opening.

Most metal window manufacturers provide standard section metal sills for fixing to the frame of their windows to give cover and protection to the wall below the window. The projection of the sill

beyond the face of the wall is determined by the 25 mm width of the welded-on stop ends, which in turn determines the position of the window in the thickness of the wall. The joint between the ends of the sill and the jambs should be pointed with mastic. The steel sill itself will exclude rainwater but the end joints may be vulnerable to water, particularly in positions of severe exposure. A dpc in the course below the sill, extending either side of the opening, might be a wise precaution in conditions of severe exposure.

Similarly, extruded aluminium section sills are made to suit aluminium windows as an integral part of the window.

## Plastic sills

Most plastic windows have an integral sill as part of the window, which fits over some form of sub-sill. Some manufacturers provide a separate hollow section plastic sill which is weathered to slope out and is designed to cover and protect the wall below the window. These separate sill sections are clipped or screwed to the frame, as illustrated in Fig. 61.

## Wood sills

Most standard section wood windows can be supplied with a wood sill section that is tongued to a groove in the sill of the frame so that it projects beyond the window either to cover and protect the wall below or to overlap a sub-sill. The sill is designed to project some 25 to 38 mm from the face of the wall as a drip edge.

Because softwood sills must be protected with a sound paint film which must be regularly maintained, otherwise rain penetration will cause rapid deterioration of the wood, it is sensible to use hardwood sills in positions of moderate and severe exposure. The sill fits between the jambs of the opening, and the end butt joints should be bedded in mortar and pointed with mastic.

## Internal sills, windowboards

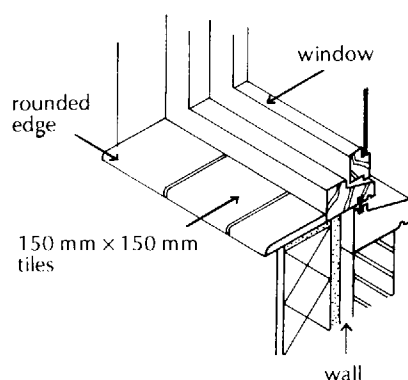


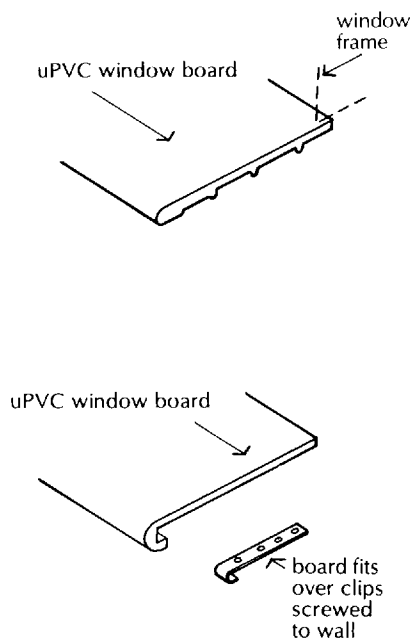
Fig. 92 Tile internal sill.

The internal sill surface to a window is covered for appearance with a painted softwood window board, clay tiles, slate, metal or plastic sections designed for the purpose. The surface of the internal sill should be such that it can easily be kept clean.

A common form of internal sill is a softwood board termed a window board, cut from 19 or 25 mm boards and wrought smooth on one face and square or rounded on one edge. The board may be tongued to fit to a groove in wood window frames. The board is nailed to plugs or bearers nailed to the wall so that it projects some 25 mm or more from the finished face of plaster, as illustrated in Fig. 86.

Clay or concrete tiles may be used as an internal sill. The tiles are bedded in mortar on the wall and pointed in cement, as illustrated in Fig. 92. Rounded edge tiles are used and laid to project beyond the plaster face.





**Fig. 93** Plastic windowboards.

Various sections of plastic windowboard are made for use with uPVC and other windows and as replacement windowboards. The thin sections are of co-extruded uPVC with a closed cell, cellular core and an integral, impact modified uPVC skin. The thicker sections are of chipboard to which a uPVC finish is applied on exposed faces.

The advantage of these windowboards is that they do not require painting and are easily cleaned. The disadvantage is that they are fairly readily defaced by sharp objects and the damage cannot be made good.

Plastic windowboards are cut to length and width with wood-working tools and fixed with concealed fixing clips, mortar bedding or silicone sealant adhesive, or are nailed or screwed to prepared timber grounds with the nail or screw heads covered with plastic caps (Fig. 93).

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## 2: Doors

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### HISTORY

Since the first early settlements, wood has been the traditional material for doors. The ready availability of the natural material which can be cut, shaped and joined with simple hand tools, made it the obvious material for making doors. In the construction of doors, from the crude cottage door of boards nailed to battens to the larger, sophisticated framed, panelled and moulded doors, there is a wide variety of types of wood to choose from to suit utility and appearance. The grain and colour of the chosen wood may be used as a decorative feature by the application of oil, wax, polish or varnish.

Wood doors are still today commonly chosen for both internal and external use. For a time, early in the twentieth century, steel, framed as fully glazed doors, was in vogue to match the then fashionable steel window. Due to the progressive, destructive corrosion these suffered and due to change of fashion, the steel door soon lost favour. Aluminium, framed mainly as fully glazed doors, was and is today used as a substitute for steel.

During the last few years plastic and steel doors have been made and used, principally as a substitute for wood doors to avoid the expense of the comparatively frequent painting that wood needs for maintenance.

Plastic doors made as a frame of corner-welded, hollow extrusions of uPVC with moulded panels of fibre glass or acrylic, pressed to resemble the appearance of a framed, panelled wood door, do not look much like a wood door, offer poor security and do not for long stand up to normal use.

Sheet steel doors pressed to shape as either flush faced doors or pressed to resemble wood panelling have been much used in North America and Northern Europe. These comparatively sturdy doors are used for domestic and commercial buildings and as fire check doors.

A door is a solid barrier that is fixed in a doorway or opening in a wall or partition to hinge, pivot or slide open or to close for access to and from buildings and between rooms, compartments, corridors, landings and stairs.

### Function

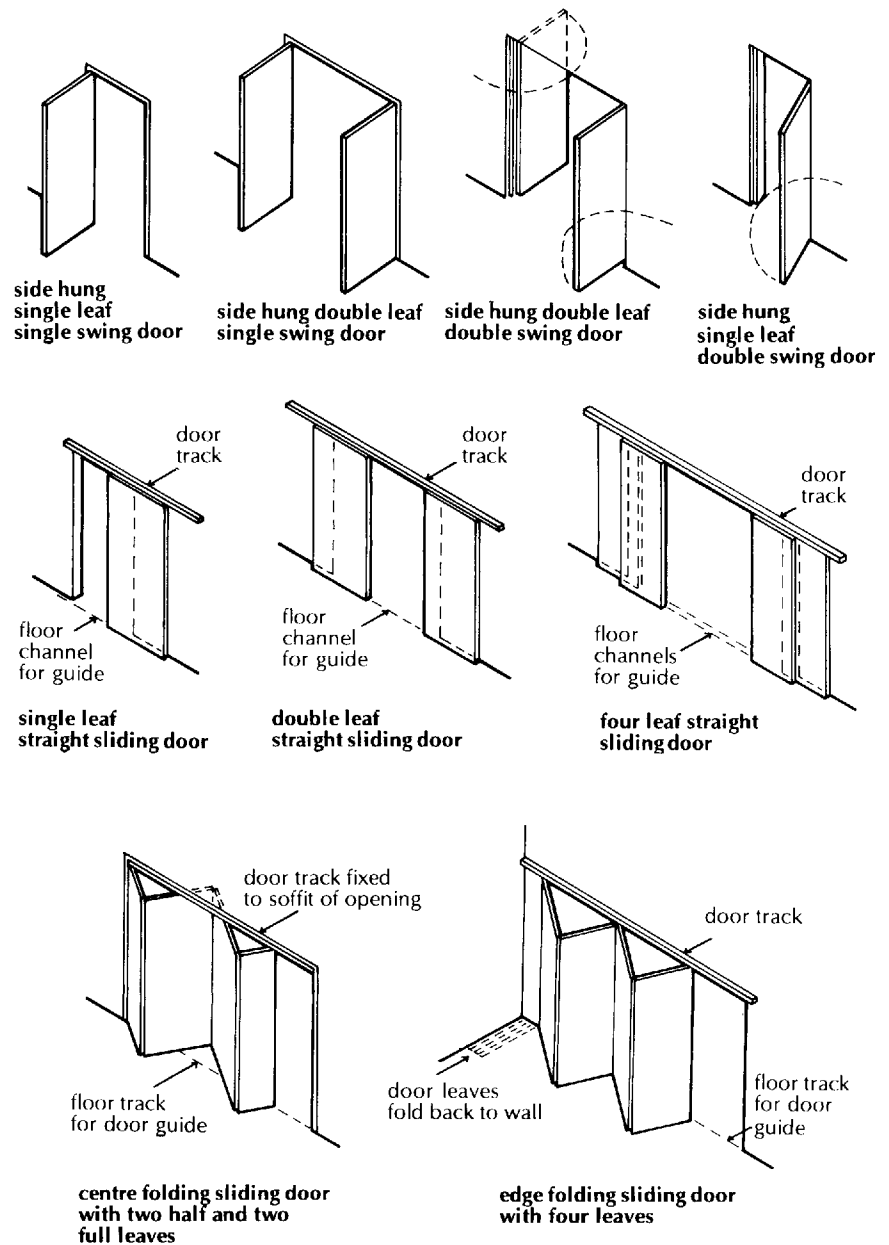
Before central or space heating of whole buildings was as common as it is today, doors served the useful purpose of containing the heat from open fires and stoves in individual rooms or compartments. Today, where buildings enjoy space heating, there is no longer a need for doors in openings to confine heating to separate rooms.

The so called 'open plan' living and working arrangements are much used, with common living areas and office working spaces.

Doors are still required for specific needs such as privacy in toilets and bathrooms, quiet in study areas, as barriers to the spread of fire and as weather barriers and security in external walls.

## DOOR TYPES

Doors are supported in openings (doorways) on hinges as side hung, on pivots as double swing and on tracks as sliding or folding doors as illustrated in Fig. 94.



**Fig. 94** Hinged, sliding and sliding folding doors.

Hinged, single swing, side hung doors are for frequent use between rooms and between rooms and corridors or landings.

Hinged and pivoted side hung, double swing doors are for frequent use along corridors to accommodate two way foot traffic.

Sliding and sliding folding doors hung on overhead track are for occasional use in openings between rooms to convert single rooms into larger double rooms.

Combinations of single swing, double swing and sliding and folding doors may be used for specific purposes.

The primary function of a door when open is:

Means of access

The functional requirements of a door, when closed, are:

Privacy

Strength and stability

Resistance to weather

Durability and freedom from maintenance

Fire safety

Resistance to the passage of heat

Resistance to the passage of sound

Security

For access alone, a doorway or opening in a wall or partition will suffice. A door is used as a barrier which can be opened for access and closed for privacy, as a barrier to transfer of heat, sound and weather and as a barrier to the spread of fire.

Before central or space heating of whole buildings was as common as it is today and when open fires and stoves were the common form of heating, doors served the very useful purpose of containing heat in separate rooms. Today this is no longer a need where whole buildings have space heating, and with changed patterns of living and working there has been a move to dispense with doors in both residential and office buildings. The so called, 'open plan' living and working arrangements are much used, with common living areas and office working spaces, and doors confined to use in toilets, bathrooms and private study or work places in houses and offices and as smoke and fire barriers.

## **FUNCTIONAL REQUIREMENTS**

### **Safety requirement**

The Approval Document to Part M of The Building Regulations suggests means of approach and minimum door sizes for doors for access to buildings for disabled people. From 25 October 1999 amendments to the Approved Document to Part M require there to be reasonable access for disabled people to and within all new dwellings, as well as other types of new buildings. The safety

requirements in the Approved Document to Part K applies to devices to stop doors that slide or open upwards from falling.

## **Means of access**

A door opening should be sufficiently wide and high for reasonably comfortable access of people. An accepted standard width and height of 762 and 1981 mm (the metric equivalent of the former imperial sizes of 2'6" × 6'6") has been established for single leaf doors. A narrower width may be adequate for a single person yet not comfortable for a person carrying things. The standard height makes allowance for all but the few exceptionally tall people. For large spaces or rooms a greater width is often adopted for appearance. The standard width and height has been chosen as convenient for the majority of people. Double leaf doors are commonly used for access to grand, large spaces or rooms for appearance, and for convenience in busy corridors.

The side on which the door is hung by hinges or pivots, its hand or handing and whether it opens into or out of a space or room, are a matter of convenience in use. By convention doors usually open into the room of which they are part of the enclosure. When single rooms were separately heated it was common to hang doors so that they opened with the leaf of the door moving towards the centre of the room, to avoid too vigorous an inrush of colder outside air. This inconvenient arrangement is reversed with space heated buildings. There have been systems of describing the hand of doors by reference to opening in or out and as either left hand, right hand or clockwise, anti-clockwise. These are of very little use because of the difficulty of clearly defining what is outside and what inside.

## **Privacy**

Doors should serve to maintain privacy inside rooms to the same extent that the enclosing walls or partitions do. For visual privacy, doors should be as obscure as the walls or partitions. For acoustic privacy doors should offer the same reduction in sound as the surrounding walls or partitions and be close fitting to the door frame or lining and be fitted with flexible air seals all round. These seals should fit sufficiently to serve as an airborne sound barrier but not so tightly as to make opening and closing the door difficult.

## **Strength and stability**

Whether it be side hinged, top and bottom pivoted, or on tracks to slide and fold, a door must have adequate strength to support its own weight and suffer knocks and minor abuses in service, as well as adequate shape stability for ease of opening and accuracy of closing to the frame or lining. Both strength and shape stability depend on the materials from which a door is made and the manner in which the materials are framed as a door.

British Standards Institution Draft for Development 171:1987 Guide to specifying performance requirements for hinged or pivoted doors gives guidance on performance criteria and was published as a prelude to the publication of a Standard.

The tests suggested are applied in general to complete door assemblies of door leaf, frame or lining and hardware because the performance of a door is affected by the component parts of door assemblies. Provision is also made for performance requirements for door leaves in isolation, to assist those manufacturers, the majority, who make doors alone rather than door sets or assemblies.

To allow for the wide range of use of doors, categories of duty related to use are suggested, from Light Duty (LD) through Medium Duty (MD) and Heavy Duty (HD) to Severe Duty (SD).

The functional requirements of doors are specified, relating to both the component parts and the whole of the door sets or assemblies, as:

Strength

Operation, the ability to be operated

Stability or freedom from excessive distortion in use

Fire resistance

Sound insulation

For external doors the additional requirements are:

Weather resistance

Thermal insulation

Security

## **Strength**

A door assembly should be strong enough to sustain the conditions of use without undue damage. The suggested tests are for resistance to damage by slamming shut or open, heavy body impact, hard body impact, torsion due to the leaf being stuck in the frame, resistance to jarring vibrations and misuse of doorhandles.

## **Operation**

A door should be easy to open, close, fasten or unfasten and should stay closed when shut. Tests for the forces required to operate door assemblies by 95% of females in the specified age groups are defined.

## **Dimensional stability**

A door should not bow, twist or deform in normal use to the extent that its appearance is unacceptable or it is difficult to open or close.

The dimensional stability of wood, metal and plastic doors is affected by temperature and humidity differences. Wood doors are affected mainly by temperature and humidity, metal doors by temperature, and plastic by thermal and hygrothermal movements.

Bow in doors is caused by differences in temperature and humidity on opposite faces, which may cause the door to bow with a curvature that is mainly in the height of the door and should not exceed 10 mm.

Twist is caused, particularly in panelled wood doors, where movement of the spiral grain, due to changes of moisture content, causes one free corner to move away from the frame. This should not exceed 10 mm.

## Durability and freedom from maintenance

## Fire safety

In the introduction to DD 171 the authors state that because aspects of performance are related to appearance, which is a subjective criterion, and the aspect of durability includes a number of factors that can be described but not quantified, they have limited the recommended tests to those concerning strength.

Doors may serve two functions in the event of fire in buildings, firstly as a barrier to limit the spread of smoke and fire and secondly to protect escape routes.

To limit the spread of fire it is usual to divide larger buildings into compartments of restricted floor area by means of compartment floors and walls. Where doors are formed in compartment walls the door must, when closed, act as a barrier to fire in the same way as the walls. For this purpose doors must have a notional integrity, which is the period in minutes that they will resist the penetration of fire.

In Approved Document B, giving practical guidance to meeting the requirements of the Building Regulations, Table B1 of Appendix B gives provisions of tests for fire resistance of doors, with minimum requirements in minutes for the integrity of doors. These are usually stated as, for example FD 20, being a provision of 20 minutes minimum integrity for a fire door.

There should be adequate means of escape from buildings in case of fire, to a place of safety outside, which is capable of being safely and effectively used at all times. To meet this basic requirement it is usual to define escape routes from most buildings along corridors and stairways which are protected by fire barriers and doors from the effects of fire for defined periods. This latter function of a fire door is described as smoke control. The majority of doors along escape routes will need to serve as fire doors to resist spread of fire and to control smoke.

Doors, which do not usually form a major part of the area of external walls, make little contribution to overall heat loss when closed, so considerations of operation, strength, stability and security are of more importance in the construction of a door than resistance to heat transfer. To minimise air infiltration and draughts, weatherstripping should be fitted where it will not appreciably impede ease of operation. As glass offers poor resistance to heat transfer it is sensible to fix double glazing to reduce heat loss through fully glazed doors.

A door should afford reduction of sound for the sake of privacy and for those functions, such as lecture rooms, where the noise level is of importance. The heavier and more massive a door the more effective a barrier it is in reducing sound transmission. A solid panel door is more effective than a flimsy hollow-core flush door. To be effective as a sound barrier a door should be fitted with air seals all round as a barrier against airborne sound. Figure 95 shows threshold seals that can be used to improve insulation against airborne sound.

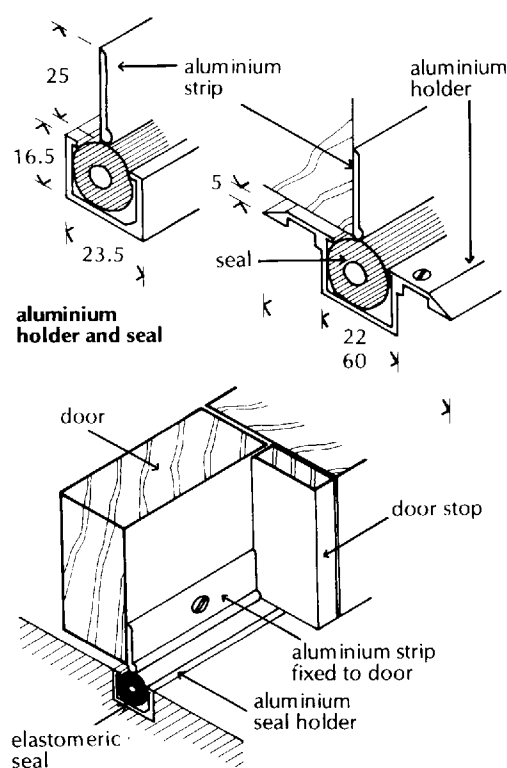


Fig. 95 Threshold seal for internal doors.

## Weather resistance

As a component part of an external wall a door should serve to exclude wind and rain depending on the anticipated conditions of exposure described for windows.

The justification and advantages of weatherstripping around an external door depend on the normal use of the door. While the advantage of weatherstripping in conserving heat and excluding draughts may outweigh the disadvantage of resistance to operating in domestic doors, which are only occasionally opened, the disadvantage of weatherstripping that reduces ease of operation in more frequently opened doors, such as shop doors, may suggest dispensing with weatherstripping.

For doors that may with advantage be weatherstripped, tests similar to those for windows are suggested.

Laboratory tests on doors show that external doors, particularly those opening inwards, are more susceptible to water leakage than windows. It is most difficult to design an inward opening external door that will meet the same standards of water tightness that are expected of windows, without the protection of some form of porch or canopy. For maximum watertightness a door will need effective weatherstripping which will to an extent make opening more difficult, and a high or complex threshold which may obstruct ease of access.

The recommendations in DD 171, therefore, suggest requirements for limited resistance to rain penetration.

## Security

An external door, particularly at the rear or sides of buildings, out of sight, is obviously a prime target for forced entry. Glazing and thin panels of wood, brittle fibre-glass and beaded plastic panels invite breakage with a view to opening bolts or latches. Solid hinges, locks and loose key bolts to a solidly framed door in a soundly fixed solid frame are the best security against forced entry.

The practical guidance in Approved Document N to the Building Regulations recommends the use of safety glass to doors and door side panels up to a level of 1500 mm above finished floor level. It is up to this level that hands, wrists and arms are vulnerable to injuries from broken glass.

## WOOD DOORS

Wood doors may be classified as (Fig. 96):

Panelled doors

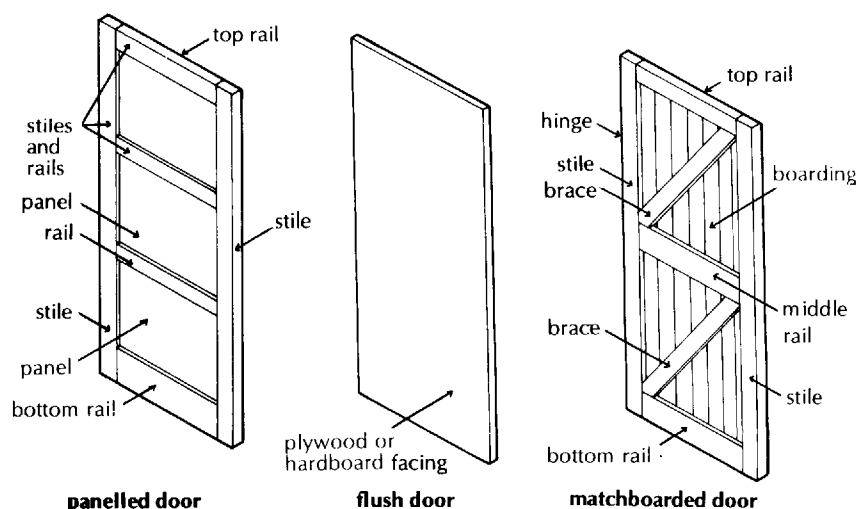
Glazed doors

Flush doors

Matchboarded doors

The traditional door is formed from solid softwood or hardwood members framed around panels. This traditional construction has





**Fig. 96** Wood doors.

been in use for centuries with little modification other than in changes in jointing techniques due to machine assembly and the use of substitute materials for wood.

During the early part of the twentieth century it became fashionable to use flush doors with plain, flat surfaces both sides, devoid of decorative moulding that matched the then current trend for plain surfaces that was considered 'modern'. This fashion persisted well into the century and it is only in recent years that it is being abandoned in favour of the old, familiar, traditional look of the panelled door. These latter doors are often by construction flush doors, with a panelled appearance.

## Panelled doors

Panelled doors are framed with stiles and rails around a panel or panels of wood or plywood. The stiles and rails are cut from timbers of the same thickness and some of the more usual sizes of timber used are: stiles and top rail 100 mm by 38 mm or 100 mm by 50 mm; middle rail, 175 mm by 38 mm or 175 mm by 50 mm; bottom rail 200 mm by 38 mm or 200 mm by 50 mm. Because the door is hinged on one side to open, it tends to sink on the lock stile. The stiles and rails have to be joined to resist the tendency of the door to sink and the two types of joint used are a mortice and tenon joint and a dowelled joint.

## Mortice and tenon joint

This is the strongest type of joint used to frame members at right angles in joinery work. Figure 97 shows the stiles and rails of a panelled door before they are put together and glued, wedged and cramped around the panels, which are not shown.

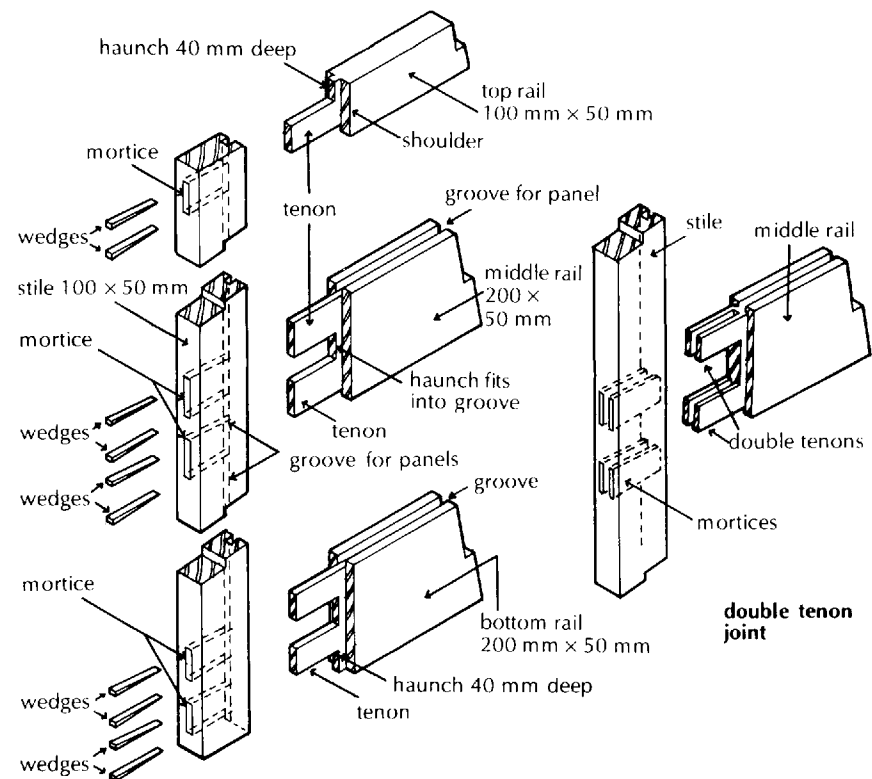


Fig. 97 Mortice and tenon joint.

## Haunched tenon

Obviously the tenons cut on the ends of the top rail cannot be as deep as the rail if they are to fit into enclosing mortices, so a tenon about 50 mm deep is cut. It is possible that the timber of the top rail may twist as it dries. To prevent the top rail moving out of upright, a small projecting haunch is cut on top of the tenon, which fits into a groove in the stile.

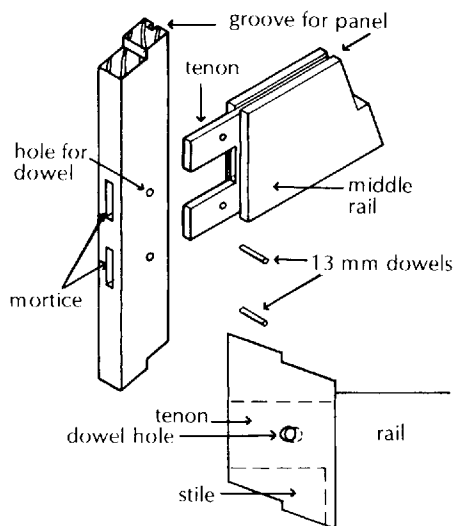
Two tenons are cut on the ends of the middle and bottom rails. It would be possible to cut one tenon the depth of the rails but the wood around the mortice might bow out and so weaken the joint. Also a tenon as deep as the rail might shrink and become loose in the mortice. To avoid this a tenon should not be deeper than five times its thickness, hence the use of two tenons on the middle and bottom rails. Double tenons are sometimes cut on the ends of the middle rail as illustrated in Fig. 97. The purpose of these double tenons is to provide a space into which a mortice lock can be fitted without damaging the tenons.

It is apparent that the joints between the middle and bottom rails and stiles are stronger than that between the top rail and stile because

of their greater depth of contact. For strength it would seem logical to make the top rail as deep as the middle rail. But a panelled door with a top rail deeper than the width of the stiles does not look attractive and by tradition the top rail is made as deep as the width of the stiles. The top and bottom faces of mortices are tapered in towards the centre of the doors so that when the tenons are fitted, small wood wedges can be driven in to make a tight fit.

## Glueing, wedging and cramping

The word cramp describes the operation of forcing the tenons tightly into mortices. The members of the door are cramped together with metal cramps which bind the members together until the glue in the joints has hardened. Before the tenons are fitted into the mortices both tenon and mortice are coated with glue. When the members of the door have been cramped together small wood wedges are knocked into the mortices top and bottom of each tenon. When the glue has hardened the cramps are released and the projecting ends of tenon and wedges are cut off flush with the edges of the stiles.



**Fig. 98** Pinned mortice and tenon.

If the timber from which a door is made shrinks, the mortice and tenon joints may in time become loose, and the door will lose shape. To prevent this, panelled doors are sometimes put together with pinned mortice and tenon joints. The mortices and tenons are cut in the usual way and holes are cut through the tenons and the sides of the mortices, as illustrated in Fig. 98. The tenons are fitted to the mortices, and oak pins (dowels) 13 mm diameter are driven through both mortice and tenon. Because the holes in the tenons and mortices are cut slightly off centre the pins, as they are driven in, draw the tenons into the mortices. Pinned mortice and tenon joints are glued and wedged. This joint should be used for heavy panelled doors.

The economic advantage of woodworking machinery cannot be exploited to the full in the cutting, shaping and assembly of mortice and tenon joints because of the number of separate hand operations involved. It is practice, therefore, to use a jointing system better fitted to woodworking machine operations in the cutting and assembly of mass produced doors

## Dowelled joints

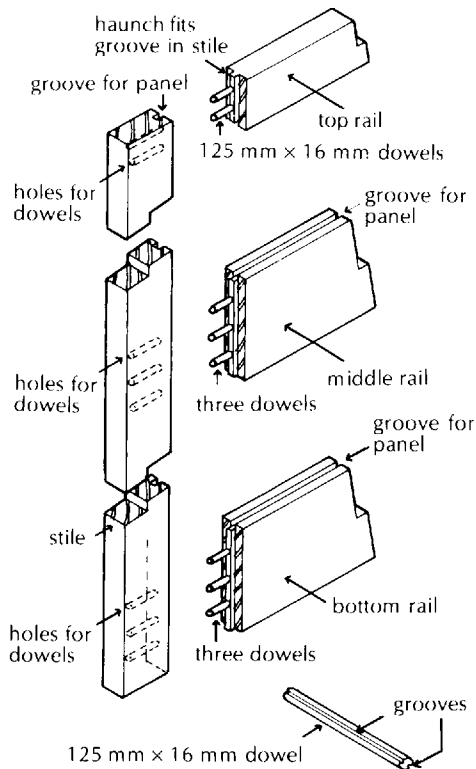


Fig. 99 Dowelled joints.

With the dowelled joint which is used to frame standard size panelled doors, continuous grooves are cut in the edges of the stiles and rails to take the panels and continuous, protruding haunches on the ends of rails as illustrated in Fig. 99. The haunches on the ends of the rails fit into the grooves cut in the edges of stiles to secure and level the members. By this arrangement the cutting of grooves and haunches are continuous operations suited to the use of woodworking machinery. Wood, plywood or wood particle board, plain panels are cut to size to fit into the grooves cut in the stiles and rails.

The rails and stiles are joined by wood dowels or pins of hardwood or the same wood as the door. Dowels which are  $125 \times 16$  mm, are grooved as illustrated in Fig. 99. The two grooves, cut along the length of each dowel, allow excess glue and air trapped in the holes to escape as the dowels are fitted in place.

At least two dowels are used for the top rail and three for the middle and bottom rails. Dowels should be spaced not more than 57 mm apart and fit half their length into each member joined. Dowels are glued and fitted to holes drilled in the members to be joined and the door is assembled with panels glued and fitted to grooves in stiles and rails and the members are cramped up. Because of improvements in glues, this type of joint will strongly frame the members of a panelled door.

## Panels

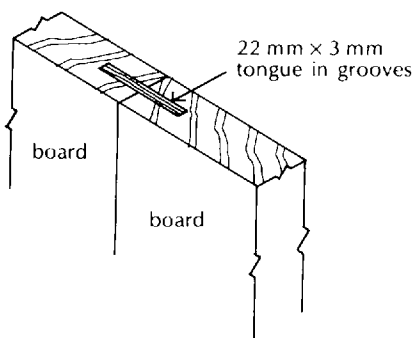


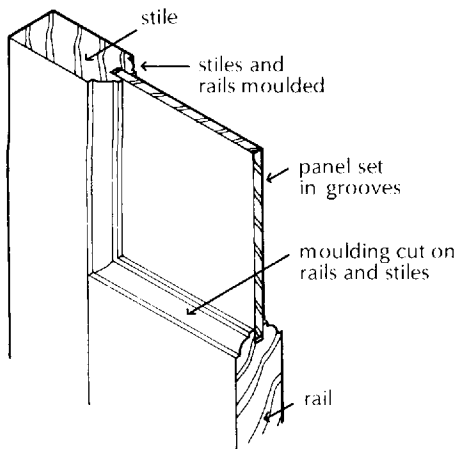
Fig. 100 Boards through tongued to form panels.

The comparatively thin wood from which panels are made will in time shrink due to loss of moisture, particularly in heated buildings. As drying shrinkage of wood occurs mainly across the long grain, panels may develop unsightly vertical cracks. On repainting, it is difficult to fill cracks successfully, as opening and closing doors tends to dislodge the filling.

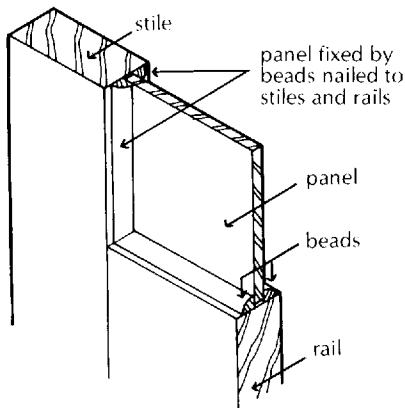
To minimise shrinkage cracking of wood panels it is practice to make panels, that are more than 250 mm wide, from boards that are tongued together.

The term 'tongued' describes the operation of jointing boards by cutting grooves in their edges into which a thin tongue or feather of wood is cramped and glued as illustrated in Fig. 100. By using boards rather than one panel, shrinkage cracking may be avoided.

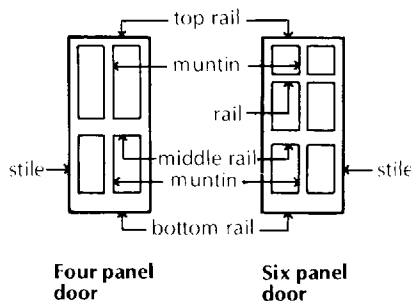
To avoid shrinkage of panels, plywood may be used. Plywood is made from three, five, seven or nine plies of thin sheets of wood firmly glued together, so that the long grain of one play is at right angles to



**Fig. 101** Framing moulded around panels.



**Fig. 102** Planted moulding.



**Fig. 103** Traditional panelled doors.

the long grain of the plies to which it is bonded. The opposed long grain of the plies strongly resists shrinkage cracking. Three-ply wood 5 or 6.5 mm thick is generally used for panels.

The traditional method of fixing and securing panels in doors is to set them into the grooves cut in the edges of the stiles and rails. To allow for drying shrinkage and any framing movements there should be a clearance of 2 mm between the edges of the panels and the bottom of the grooves in which they are set.

The advantages of setting panels in grooves in the framing members is that the panels are securely fixed in place and that shrinkage and movement of the frame will not cause visible cracks to open up around panels.

Panels set in grooves in stiles and rails with square edges may have a plain, unfinished look. To improve the appearance of a panelled door, mouldings are cut on the edges of the stiles and rails around panels as illustrated in Fig. 101. For this finish the ends of rails have to be scribed to fit around the moulding cut on the stiles. The term 'scribed' describes the operation of cutting the wood to shape to fit closely around the moulding which is cut continuously down the length of the stile.

A cheaper, inferior method of giving the appearance of mouldings around panels is to plant (nail) moulded timber beads around each panel as illustrated in Fig. 102. Due to the inevitable drying shrinkage, cracks will in all likelihood open up between the planted beads and the framing and panels of doors.

The traditional panelled door was constructed with four or six panels with central framing members, termed muntins, tenoned to rails as illustrated in Fig. 103. The advantage of this arrangement is that the width of the panels is limited to reduce the possibility of shrinkage cracks and the shape of the panels emphasises the verticality of the door. The four panel design is for small and the six panel design for larger doors. For appearance sake the six panel door is usually finished with mouldings cut on stiles, muntins and rails both sides.

The joint between the vertical muntins and the rails in the frame of four and six panelled doors is usually made with a stub tenon. A stub tenon cut on the ends of muntins fits to a mortice not cut right through the top and bottom rails to avoid the end grain of a tenon being exposed. These stub (short) tenons are glued and cramped up with the framing members around the panels.

For the sake of economy in using woodworking machinery and a change in fashion, standard, panelled wood doors are made without

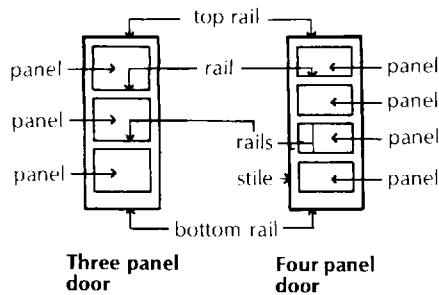


Fig. 104 Standard interior panelled doors.

### Doors with raised panels

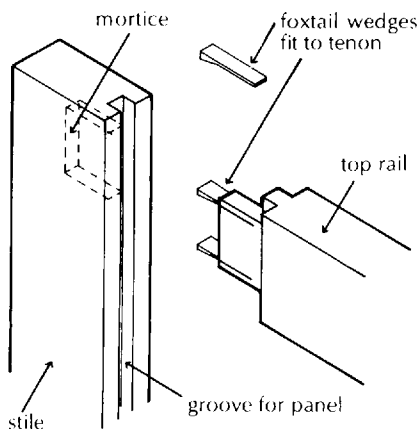


Fig. 105 Foxtail wedges.

muntings with panels between the stiles of the framing as illustrated in Fig. 104. These comparatively wide panels are usually of plywood, to minimise shrinkage cracking, and set in grooves in the framing members. For economy these doors are often finished with square edges framing around the panels.

These standard doors which are moderately robust for use as internal doors are not suited for use as external doors for other than sheltered positions.

For appearance sake, entrance doors and doors to principal rooms in both domestic and public buildings are often made more imposing and attractive by the use of panels that are raised, so that the panel is thicker at the centre than at the edges. This involves a deal of wasteful cutting of wood. Such doors are often made of hardwood which is finished to display the colour and grain of the wood by polish or French polish.

To avoid the ends of tenons showing on the edges of the door, it is practice to use stub tenons which are secured with foxtail wedges as illustrated in Fig. 105. The foxtail wedges fit to saw cuts in the ends of the stub tenons so that when the tenon is cramped into the mortice the wedges spread the tenon to bind to the mortice. This type of joint, which has to be very accurately cut, makes a sound joint. As an alternative dowelled joints may be used.

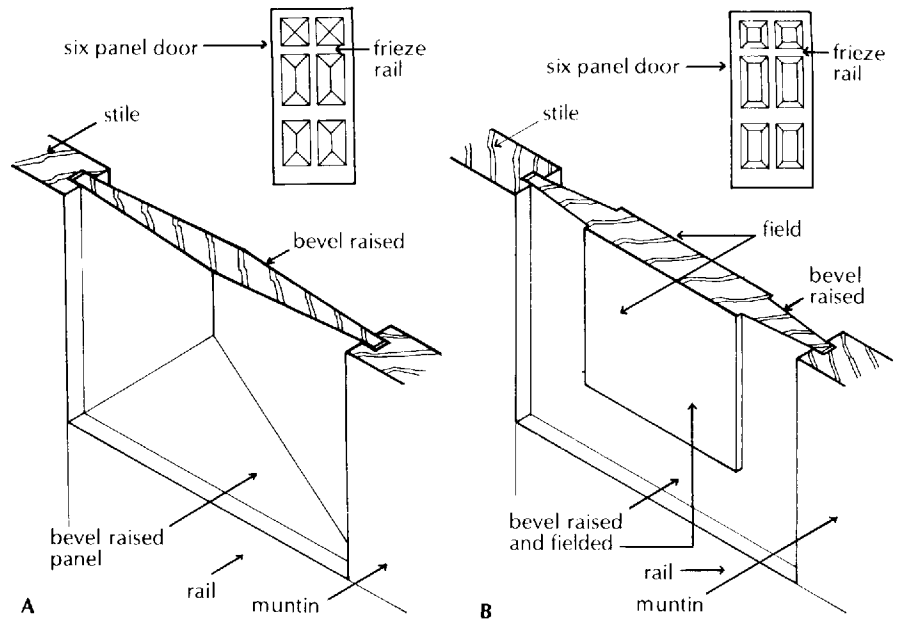
Raised panels are either bevel raised, bevel raised and fielded, or square raised and fielded.

### Bevel raised panels

The panels are cut with four similar bevel faces each with a shallow rise from the edges of the panel to a point with square panels and ridge with rectangular panels as illustrated in Fig. 106A.

### Bevel raised and fielded panels

The panels are cut with four similar bevel faces rising from the edges of the panel to a flat surface, termed the field, which is emphasised by a slight sinking cut around it as illustrated in Fig. 106B. At the field the panel is either as thick as or slightly less thick than the stiles. The proportion of the fielded surface to the whole panel is a matter of taste.

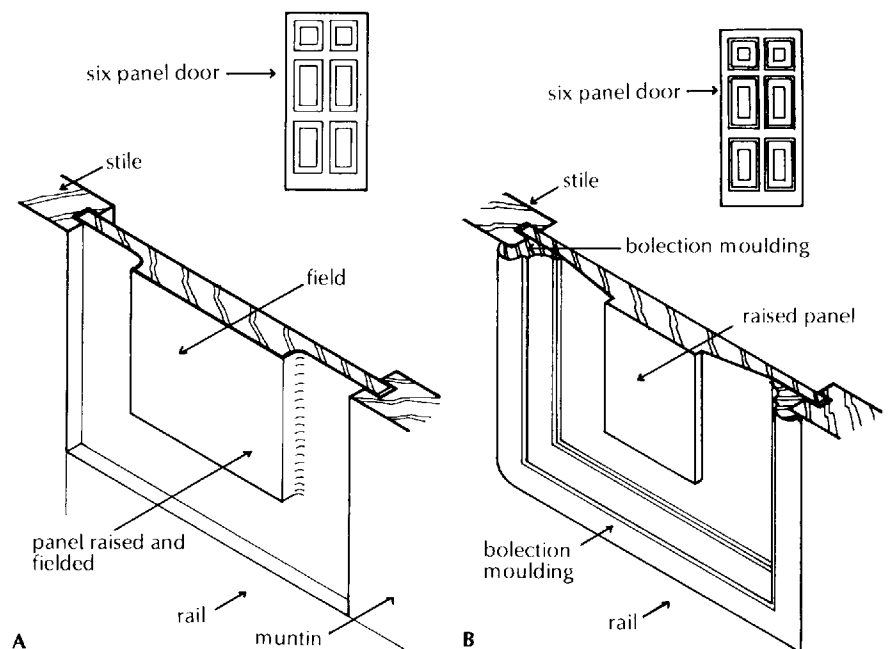


**Fig. 106** A bevel raised panels. B bevel raised and fielded panels.

### Raised and fielded panel

The panel, which is of uniform thickness around the edges, is raised to a flat field at the centre with a shallow sinking as illustrated in Fig. 107A, the field being square or rectangular depending on the shape of the panel.

Panels may be raised on both sides, as shown in Fig. 106A, or on one side only, as illustrated in Fig. 107A.



**Fig. 107** A raised and fielded panels. B bolection moulding.

## Bolection moulding

A bolection moulding is planted (nailed) around the panels of a door for the sake of appearance. The moulding is cut so that when it is fixed it covers the edges of the stiles and rails around the panel for the sake of emphasis, as illustrated in Fig. 107B. This particular section of wood moulding may be used with both raised and fielded panels on one or both sides of a door.

Practice is to employ bolection mouldings around the panels of large doors as this moulding looks clumsy and bulky around small panels.

## Double margin door

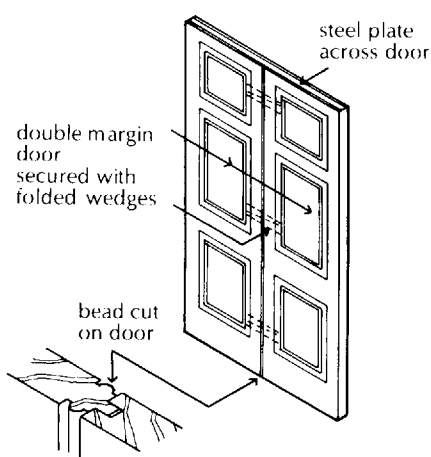


Fig. 108 Double margin door.

A wide panelled door may be constructed as one door or as two doors hinged to meet in the middle. A single door would tend to look clumsy with over size panels, whereas two doors would each be too narrow for comfortable access when only one leaf is opened. As a compromise such doors can be made up as if they were two doors with the two doors fixed together and acting as a single door as illustrated in Fig. 108.

The two leaves of this door are framed as conventional panelled doors, with plain or raised or fielded panels, and the stile of one leaf tongued into a groove in the other. A bead (quirk) is cut on the edges of the stiles in the middle of the door to distinguish the two separate leaves.

To fix the two leaves of this single door together pairs of folding wedges are fitted to mortices in the joining stiles and glued and cramped together. Folding wedges are tapered sections of wood, cut from a piece of wood, and fitted together on their tapered edges so that when they are forced together along the taper, they expand inside the mortice.

To provide additional bonding of the two leaves of this door, steel plates are set in a groove in the top and bottom edge and secured with screws.

## Solid panels – flush panels

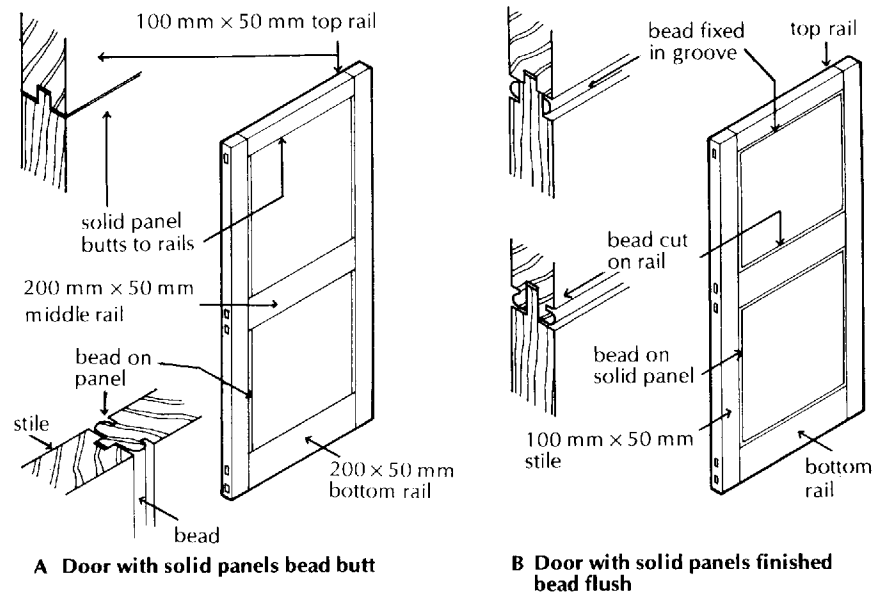
Solid panel doors are constructed with panels as thick as the stiles and rails around them for strength, security or where the door acts as a fire check door.

These doors are usually constructed of hardwood, such as oak, that has a better resistance to damage by fire than softwood. The solid panels are tongued to grooves in the stiles and rails and are either cut with a bead on their vertical edges or with a bead all round each panel for appearance sake.

Timber shrinks more across than along its long grain and because the long grain in these panels is arranged vertically the shrinkage at the sides of the panels will be more than at top and bottom. For this reason beads are cut on the vertical edges of the panels to mask any shrinkage cracks that might appear, as illustrated in Fig. 109. Where beads are cut top and bottom they are cut on the rails as it is easier to

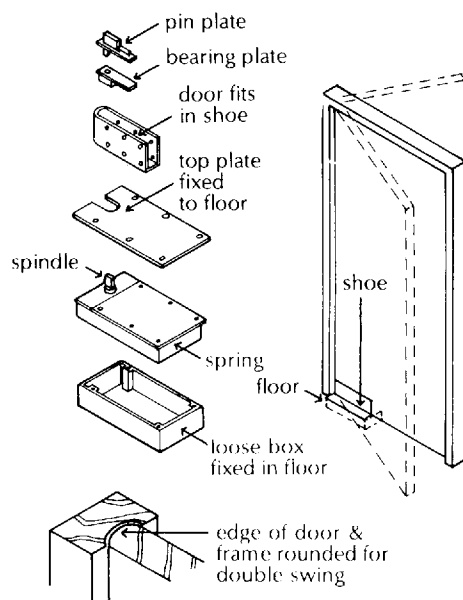


cut a bead along the grain of the rails than across the end long grain of the panels. A panel with beads on its vertical edges only is described as bead butt and one with beads all round as bead flush (Fig. 109). As an alternative to horizontal beads cut on the stiles a planted bead can be used, as illustrated in Fig. 109. This is not satisfactory with external doors as water may get behind the bead which may then swell and come away.



**Fig. 109** A Solid panels bead butt. B Solid panels bead flush.

## Double swing doors



**Fig. 110** Double swing door.

Double swing doors are used at the end of and along busy corridors and as shop entrance doors for the convenience of two way foot traffic. As it is easier and quicker to push than pull a door open, this type of door is used for the convenience of passing through the doorway in either direction. To avoid the danger of the door being pushed simultaneously from both sides these doors are constructed with either a glazed top panel or they are fully glazed.

To allow for the double swing action of the door the vertical edges of the door are rounded to rotate inside a rounded rebate in the timber door frame as illustrated in Fig. 110.

The door is either hung on double action hinges designed to accommodate the double swing or supported by double action floor springs and a top pivot as illustrated in Fig. 110. The door is supported by a shoe that fits to the spindle of the double action spring which fits into a box set in the floor. A top plate, which is screwed to the spring box, finishes flush with the floor.

A bearing plate, fixed to the top of the door, fits to a pin protruding from a plate fixed to the door frame.

Because of the necessary clearance gaps around the door, it provides poor thermal and acoustic resistance.

## Sliding and sliding folding doors

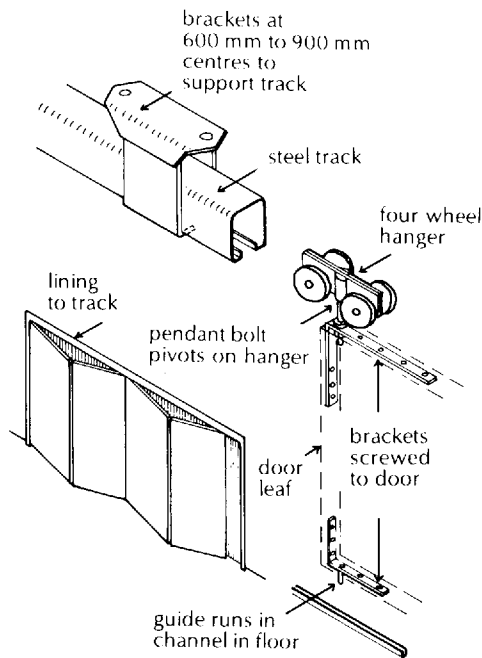


Fig. 111 Sliding folding door.

Sliding doors are designed mainly for occasional use to provide either a clear opening or act as a barrier between adjacent rooms or spaces to accommodate change of use or function and where it is necessary to avoid the obstruction caused by a hinged leaf.

Sliding doors can only be used where there is room for the door or doors to slide to one or both sides of the opening. These doors may slide as two leaves, one to each side or as one leaf to one side of the opening.

Sliding folding doors are used to separate rooms or spaces where it is convenient to be able to join the two rooms or spaces for their full width each side of the opening. Because of the folding sliding action the hinged leaves of the door can slide and fold back against a wall to occupy little space.

Sliding and sliding folding doors should be hung on an overhead track fixed to the timber or steel beam over the opening. An inverted 'U' shaped track is fixed to the beam with brackets as illustrated in Fig. 111. Hangers, in the form of a four wheeled trolley, run in the overhead track and support the door leaves through brackets screwed to the doors.

At the bottom of the door a channel, set and fixed in the floor, acts as a guide to a pin or wheel fixed by brackets to the door. To maintain a reasonably easy movement of sliding doors it is necessary to keep the bottom guide track free from dirt that might obstruct movement and to keep the hangers reasonably oiled.

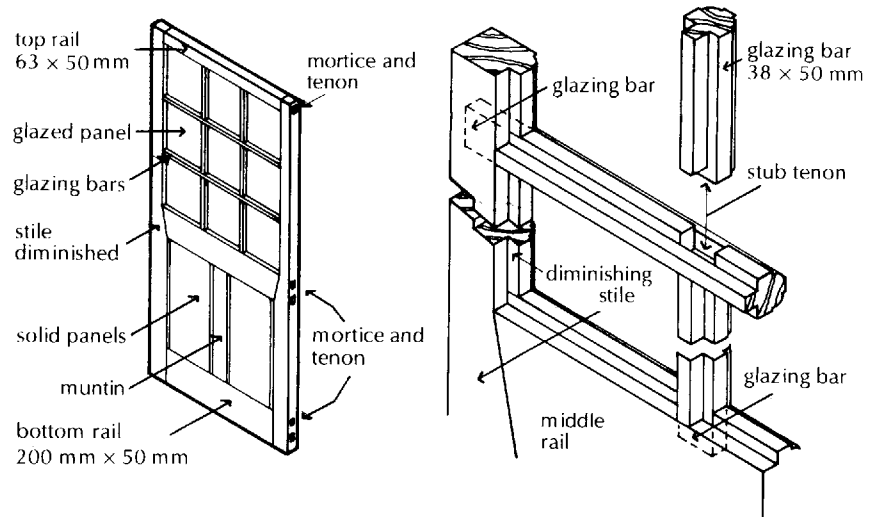
The door leaves of both sliding and sliding folding doors may be of either panelled or flush construction. The lighter the doors, the easier their movement and the heavier the better they serve as a sound barrier.

## GLAZED DOORS

Doors with one or more glazed panels of glass or fully glazed are used to give some daylight to spaces such as halls that have no windows and to give some light from a window, through an internal door, to an otherwise unlit space. Fully glazed doors fixed in an external wall serve as both door and window in the form of the fully glazed, sliding patio doors, described and illustrated in the previous chapter.

## Purpose made glazed doors

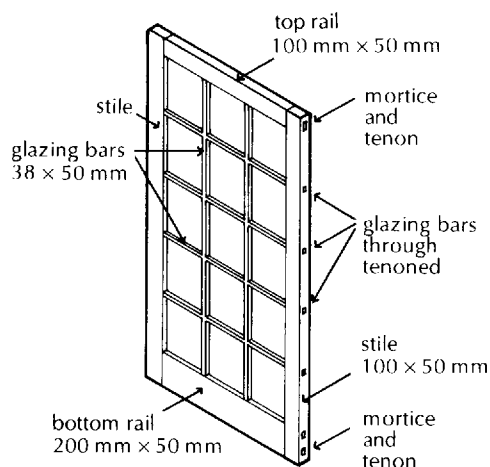
A common form of traditional wood door for external use has glazed upper panels to admit daylight to halls. This door is framed as solid lower panels with upper glazed panels. The door may be framed as a normal panelled door with continuous width stiles or with diminishing stiles to provide a greater width for glazing as illustrated in Fig. 112.



**Fig. 112** Glazed door with diminishing (gun stock) stiles.

The lower panels are made solid and bead butt. The upper part of the door may be glazed in one square of glass or more usually as several squares of glass in putty or glazing beads in glazing bars. The glazing bars are through tenoned to stiles and stub tenoned to rails as illustrated in Fig. 112. Because the stiles are diminished in width at the middle rail, they are sometimes referred to as 'gunstock stiles' for their resemblance to the stock of a gun.

## French casement



**Fig. 113** Casement door (French casement).

The traditional form of first floor window to many French and northern Mediterranean countries is in the form of a timber framed door, fully glazed as illustrated in Fig. 113. The door is made with vertical and horizontal glazing bars as part of the framing.

These doors serve as windows to the first floor rooms and as doors, opening in, for access to balconies and ventilation during summer. Louvred timber shutters are hung externally to close over the window opening to exclude summer sun and provide ventilation.

These French casements (French doors) are framed with timber stiles and rails through tenoned together with the horizontal glazing bars through tenoned to the stiles as part of the frame structure.

Because they are hung to open in it is difficult to provide a weathertight seal, particularly at the sill of the door frame. These external doors need careful maintenance as protection against wind-driven rain else they will deteriorate and become difficult to open and close. As security against wind pressure they are usually fitted with bolts top and bottom.

## FLUSH DOORS

Since they were first introduced early in the twentieth century flush doors have been much used internally in flats and houses. The plain, flat faces of these doors, without panels, appealed to the urban

dwellers of the expanding towns of the time and their low cost to the builders. Fashions change and 'flush' doors today are made with faces press moulded to provide a poor imitation of a panelled door to satisfy the nostalgia for the old that is current today.

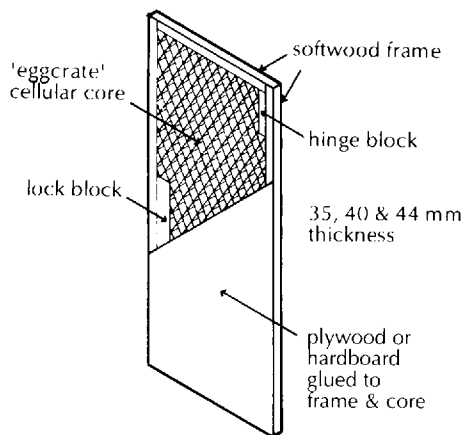
A variety of flush doors is manufactured with plain flush faces both sides and fibreboard facings press moulded, often with comparatively shallow sinkings, to resemble the appearance of panelled doors.

The shape stability of these doors depends to an extent on the fixing of the flush or moulded facings to the core; the lighter and thinner the core the more the facings are used to provide stability. With a lightweight cellular or skeleton core the fixing of the facings is generally adequate to maintain the square face and shape of the door but may well not be substantial enough to resist torsion, where one free corner of the door will no longer fit closely into the rebate of the frame or lining.

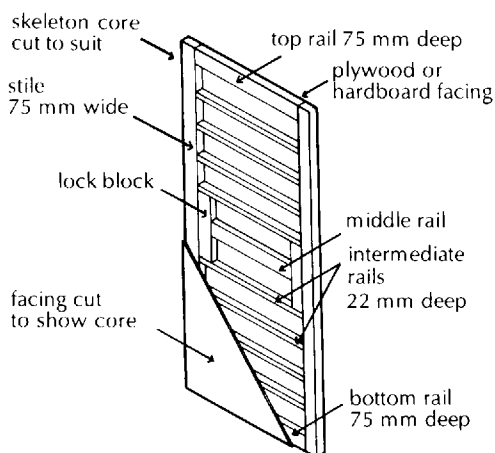
With cellular core and skeleton framed doors there may be a tendency for the flush facings to show the pattern of the core or skeleton, particularly where the faces are painted with a gloss paint.

The heavier solid core flush doors with a core of laminated timber, flaxboard, chipboard or compressed fibre strips will tend to maintain shape stability and uniformity of surface facings better than the light cellular and skeleton core doors.

Where the facings are of hardboard, press moulded to simulate door panels, the core is of light section softwood framed as a fixing for the four edges of the door and the fake internal rails and muntins.



**Fig. 114** Cellular core flush door.

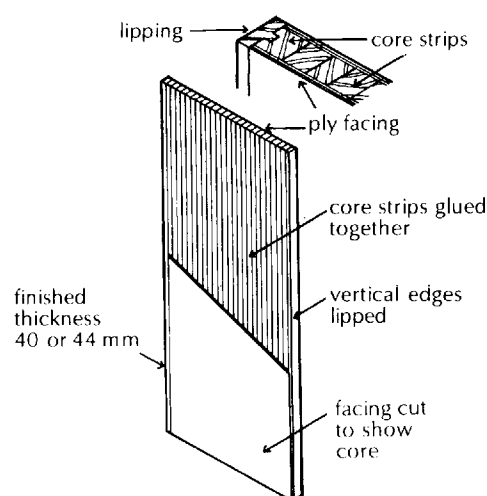


**Fig. 115** Skeleton core flush door.

Cellular core flush doors are made with a cellular, fibreboard or paper core in a light softwood frame with lock and hinge blocks, covered with plywood or hardboard facings glued to the frame and core both sides as illustrated in Fig. 114.

These flimsy, lightweight doors are for light duty such as internal domestic doors. They do not withstand rough usage such as the movements of boisterous children and provide poor acoustic privacy, security or fire resistance. They are mass produced in a small range of standard sizes and are cheap.

Skeleton core flush doors are made with a core of small section timbers, as illustrated in Fig. 115. The main members of this structural core are the stiles and rails, with intermediate rails as shown, as a base for the facing of plywood or hardboard. The framing core members are joined with glued, tongued-and-grooved joints. The door illustrated in Fig. 115 has a skeleton core occupying from 30% to 40% of the core of the door. This is a light duty door suitable for internal domestic use. A similar skeleton core flush door with more substantial intermediate rails in the core, where the core occupies



**Fig. 116** Solid core (lamine) flush door.

from 50% to 60% of the core, is a medium duty door suitable for use internally in domestic and public buildings and for external use in sheltered positions.

This somewhat more substantial door will withstand normal use and maintain its shape stability better than a cellular core door.

Solid core flush doors are made with a core of timber, chipboard, flaxboard or compressed fibre board strips. The solid core door illustrated in Fig. 116 has a core of timber strips glued together, with plywood facings both sides glued to the solid core. The door is edged with vertical lipping to provide a neat finish.

Because of the solid core these doors have somewhat better shape and surface stability and acoustic resistance than the cellular or skeleton core flush doors.

The chipboard, flaxboard and compressed fibre board strip core doors are made with a solid core enclosed in a light timber frame to which hardboard or plywood is fixed. These solid core doors are more expensive than cellular core or skeleton core doors.

Solid core flush doors may be used as fire doors with an integrity rating of 20 or 30 minutes.

## FIRE DOORS

Fires in buildings start, more often than not, by the heating of some material of the contents to ignition and the beginning of a fire. In the early stages of the growth of a fire the considerable volume of smoke produced rises to fill rooms from the ceiling downwards and spreads through gaps around doors and through unsealed void space, making a danger to people in the building. Fires grow and spread through the release of the hot, flammable, gaseous products of combustion to other materials of the building and its contents.

## Means of escape

To provide safe means of escape for the occupants of buildings in the early stages of a fire, smoke control fire doors are fixed in enclosures to and along escape routes.

To limit the spread of fire in buildings it is usual to divide all but small buildings into compartments surrounded by floors and walls capable of limiting the spread of fire for a stated period of minutes or hours. Doors in compartment walls and doors to a protected escape route should be capable of resisting the spread of fire to the same extent that the enclosing walls do. These doors, which in the past have been variously described as fire check doors, fire break doors, fire protection doors and fire resisting doors, are now simply termed fire doors.

Fire doors serve to protect escape routes and the contents and structure of buildings by limiting the spread of smoke and fire. Fire

doors that are fixed for smoke control only should be capable of withstanding smoke at ambient (surrounding) temperatures and limited smoke at medium temperatures by self closing devices and flexible seals. Fire doors that are fixed to protect means of escape routes should withstand smoke at ambient and limited smoke at medium temperatures and have a minimum fire resistance, for integrity only, of 20 minutes.

Fire doors that are fixed as part of a fire compartment and as isolation of special risk areas should have a minimum fire resistance, for integrity only, of a period of minutes or hours appropriate to the periods set out in Approved Document B giving practical guidance for the requirements of the Building Regulations, Fire safety.

### Fire resistance integrity

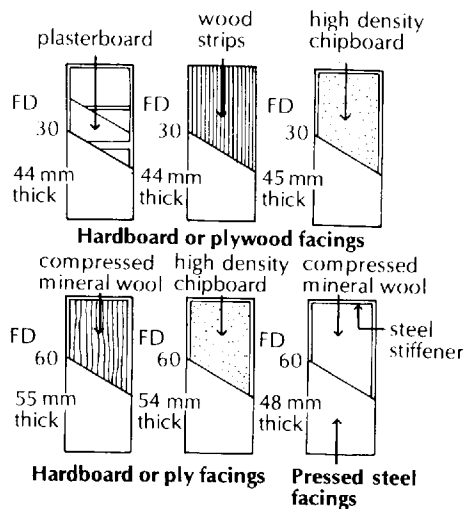


Fig. 117 Fire doors.

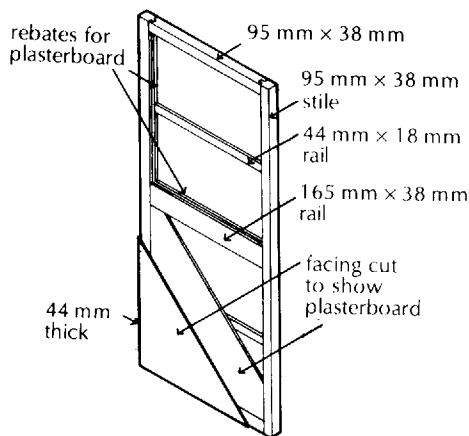


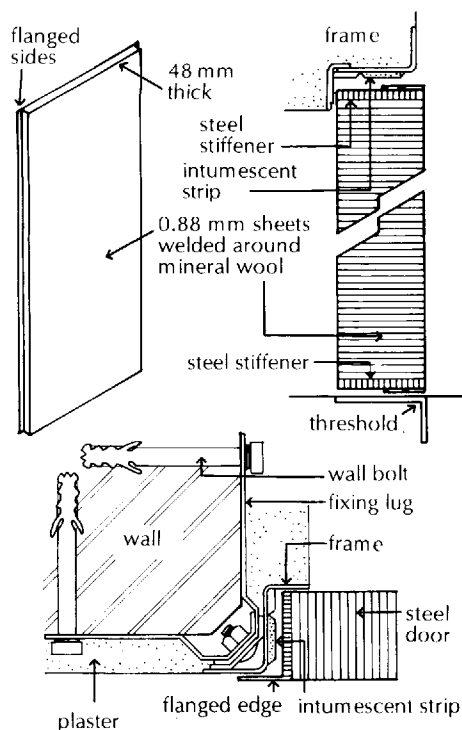
Fig. 118 Standard  $\frac{1}{2}$  hour fire door.

To conform to international practice, doors and other non-load-bearing elements are no longer assessed for stability (resistance to collapse) or insulation. The test for integrity is assumed to include performance in regard to stability and insulation. The notation for fire doors is FD followed by the figure in minutes for integrity, as for example FD 20 or FD 30, and doors that serve for smoke control as for example FD 20S.

The performance test for fire doors that serve as barriers to the spread of fire is determined from the integrity of a door assembly or door set in its resistance to penetration by flame and hot gases. The test is carried out on a door assembly which includes all hardware, supports, fixings, door leaf and frame, representative of a door assembly that will be used in practice. Each face of the door assembly is exposed separately to prescribed heating conditions from a furnace, on a temperature-time relationship, to determine the time to failure of integrity. Failure of integrity occurs when flame or hot gases penetrate gaps or cracks in the door assembly and cause flaming of a cotton wool pad on the side of the assembly opposite to the furnace.

The door leaves illustrated in Fig. 117 are constructed and faced to provide 30 and 60 minutes for integrity. The 30 minute skeleton core flush door is protected with plasterboard panels fixed to the skeleton core under the plywood or hardboard facings as illustrated in Fig. 118.

The 30 minute, solid core fire doors are protected with wood strips or high density chipboard covered with plywood or hardboard facings.



**Fig. 119** Flush steel fire door.

The 60 minute, solid core fire doors are protected with compressed mineral wool or high density chipboard and hardboard or plywood facings.

The flush, steel fire door to provide 60 minutes protection, shown in Fig. 117 and illustrated in Fig. 119, has welded sheet steel facings. The casing is pressed around steel stiffeners and a core of compressed mineral wool. The door is provided with intumescent seals and is hung on a pressed steel frame.

A fire door should at once be easy to operate, serve as an effective barrier to the spread of smoke and fire when closed and be fitted with some effective self closing device. For ease of operation there must be clearance gaps around the door leaf. These clearance gaps are effectively sealed when a door leaf closes into and up to the rebate in a door frame. Where a door leaf has distorted in use and when the leaf is distorted by the heat of a fire, then the leaf will no longer fit tightly inside the rebate of the frame and smoke and flame can spread through the gaps around the door leaf. As a barrier to the spread of smoke, flexible seals should be fixed between door leaves and frames and as a barrier to the spread of fire, heat activated (intumescent) seals should be fitted.

Smoke control door assemblies (FDS) that serve only as a barrier to the spread of smoke without any requirement for fire resistance, such as fire doors along an escape route, may be fitted in rebated frames or hung to open both ways. To provide an effective seal against the spread of smoke through gaps around these doors, flexible seals should be fitted.

Smoke control door assemblies that serve as a barrier to the spread of smoke and fire, such as doors leading to a protected escape route, should be hung in rebated frames and tested for a minimum integrity of 30 minutes against the spread of fire, and should be fitted with heat activated (intumescent) seals and flexible edge seals against the likelihood of the door leaf deforming.

Fire door assemblies fixed in compartment walls and to enclosures to special risk areas should be hung in rebated frames and tested for integrity for not less than 30 minutes or such period as detailed in Advisory Document B to the Building Regulations, and should be fitted with the intumescent seals. The currently accepted minimum size of a softwood door frame for a fire door is 70 × 30 mm exclusive of a planted stop.

## Heat activated intumescent seals

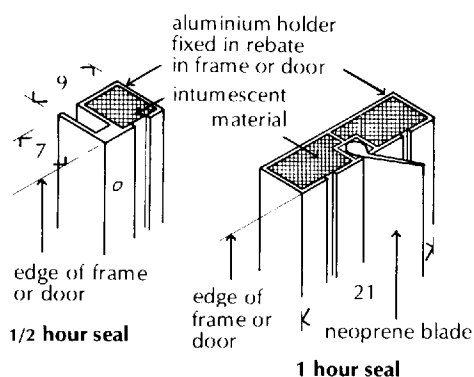


Fig. 120 Intumescent fire seal.

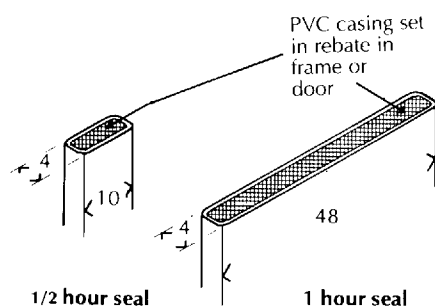


Fig. 121 Intumescent fire seal.

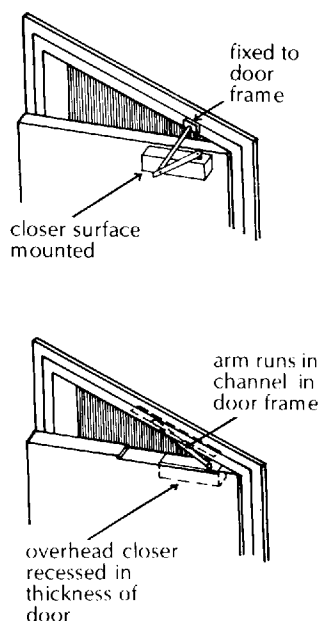


Fig. 122 Overhead door closer.

An intumescent seal is made of a material that swells by foaming and expanding at temperatures between 140°C and 300°C.

The intumescent seals illustrated in Fig. 120 consist of aluminium holders inside which the intumescent material is held. The aluminium holders are fixed in a rebate to the edges of doors or to the door frames. When the temperature rises sufficiently the intumescent material inside the holders expands out through the vertical slots in the holder and effectively seals the door in the frame as a barrier to the spread of flame.

The neoprene blade shown in the 1 hour seal acts as a seal against smoke that occurs in the early stages of a fire before the intumescent material is sufficiently hot to expand.

The intumescent seals shown in Fig. 121 comprise a PVC casing in which the intumescent material is held. The seals are set in rebates in the edges of the door or in the rebate of the frame. As the temperature rises the thermoplastic PVC casing gradually softens so that when the temperature has risen sufficiently, the intumescent material expands, ruptures the PVC casing and acts as a seal around the door.

For a fire door to be effective against smoke and the spread of fire it should, when not in use, be positively closed to the frame by some self closing device. The door closers that are used are overhead door closers or one of the floor springs illustrated in Fig. 110.

The overhead door closers illustrated in Fig. 122 consist of a hydraulically operated cylinder in a metal casing that is either screwed to the door face or set in a housing in the top of the door leaf for appearance sake. Pivoted arms, one to the housing and one attached to the door frame, act to automatically close the door to the frame, after the door has been opened.

Because these door closers are fixed to doors that are generally in frequent use they require regular maintenance if they are to serve their purpose.

The current requirement for fire doors is that complete door assemblies be tested in accordance with BS 476 and certified as meeting the recommendations of performance for integrity and noted, for example, as FD20, FD30 as satisfying the requirements for 20 and 30 minutes integrity respectively.



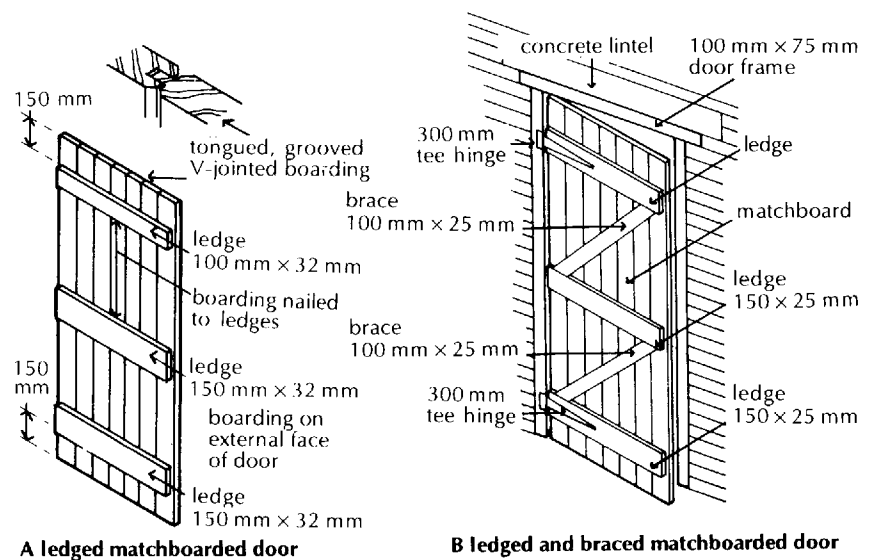
## MATCHBOARDED DOORS

These utilitarian doors are made with a facing of tongued, grooved and V-jointed boards which are nailed to horizontal ledges, braces between ledges or to a frame. These relatively crude doors are sometimes described as 'matchboarded' doors because of the comparatively thin boards from which they are made or as 'cottage doors' for their use in the traditional country cottage.

The simple ledged doors are used for sheds and cellars and the framed doors for garages and industrial buildings where the width of the door and its use as an external door justify the more expensive construction. Appearance is not considered as an important consideration in the choice of these doors.

### Ledged matchboard doors

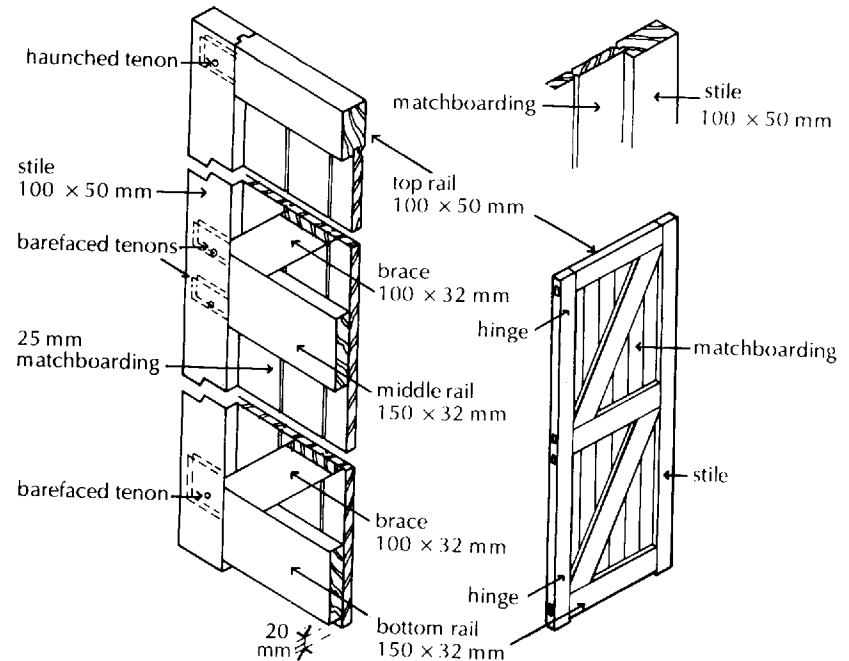
Ledged matchboard doors are made by nailing matchboards to horizontal ledges, as illustrated in Fig. 123A. The nailing of the boards to the ledges does not strongly frame the door, which is liable to sink and lose shape. This door is used for narrow openings only.



**Fig. 123** A ledged matchboarded door.  
B ledged and braced matchboarded door.

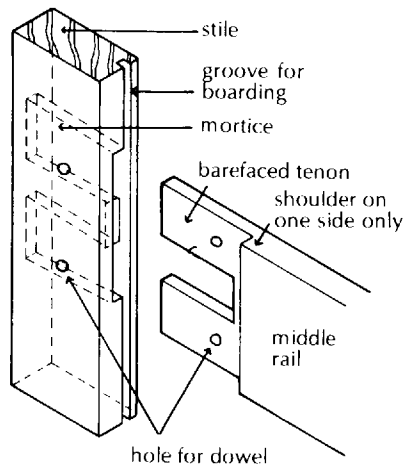
### Ledged and braced matchboarded door

Ledged and braced matchboarded doors are strengthened against sinking, with braces fixed between the rails at an angle to resist sinking on the lock edge (Fig. 123B). The matchboarding is nailed to ledges and braces.



**Fig. 124** Framed and braced matchboarded door.

### Framed and braced matchboarded door

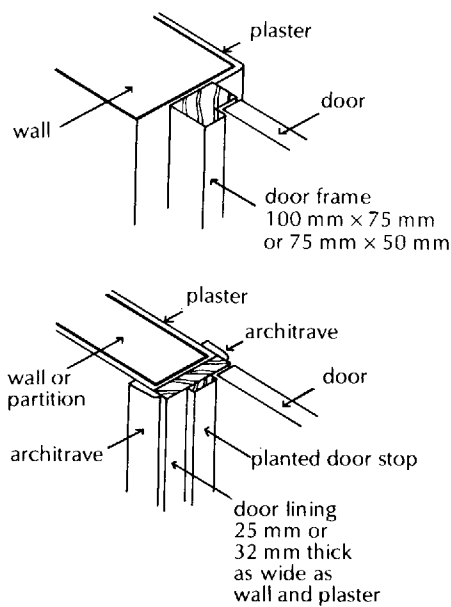


**Fig. 125** Barefaced tenon.

Framed and braced matchboarded doors are made by nailing matchboarding to a frame of stiles and rails that are framed with mortice and tenon joints with braces to strengthen the door against sinking, as illustrated in Fig. 124. The boarding runs from the underside of the top rail, to protect the end grain of the boards from rain, and is carried down over both middle and bottom rails. To allow for the boards running over them the middle and bottom rails are less thick than the stiles to which they are joined with a barefaced tenon joint (Fig. 125). This joint is used instead of the normal joint with two shoulders, so that the tenon is not too thin. These doors are used for large openings to garages, factories and for entrance gates.

### DOOR FRAMES AND LININGS

A door frame is made of timbers of sufficient cross section to support the weight of a door and to serve as a surround to the door into which it closes. The majority of door frames are rebated to serve as a stop for one way swing doors. The door frame is secured in the wall or partition opening to support external doors and heavier internal doors.



**Fig. 126** Door frame and door lining.

Door linings are thin sections of wood or metal that are fixed securely in a doorway or opening as a lining around the reveal (thickness) of the wall or partition.

A door lining which may not be substantial enough by itself to support the weight of a door will depend on its fixing to the wall or partition for support. Figure 126 illustrates the difference between a door frame and a lining.

The choice of a door frame or lining is to an extent a matter of appearance and convenience in fixing and methods of masking the junction between plaster finishes and frames and linings.

Door linings are generally used for internal doors in thin partitions where the width of the lining is the same as the thickness of the partition and wall plaster both sides. In this way the junction of the plaster and lining can be masked by an architrave and the door opening emphasised by the lining and architrave.

Door frames, commonly used for external doors and heavier internal doors, may not be as wide as the thickness of the wall in which they are fixed as illustrated in Fig. 126. It is necessary, therefore, to run plaster finishes around the angle of the wall, into the reveal and up to the door frame. In time the junction between the plaster and frame will open up as an unsightly crack. A wood bead fixed to hide this potential crack, may itself show cracks in time. More substantial linings, or combinations of frames and linings, are used for panelled doors in walls that are one brick or more thick to combine the strength of a frame with the appearance of a lining.

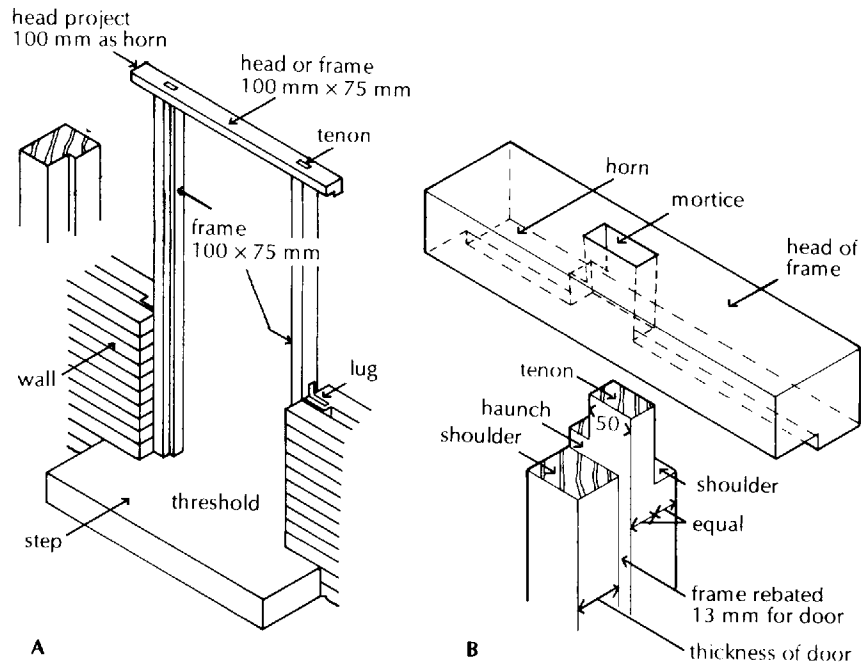
Door frames are usually built-in as the brick or block partition is raised for the convenience of building around the frame. A disadvantage of this is that the frame may suffer damage during subsequent operations. Door linings which are fixed in position after the roof of the building is on, will suffer less damage than built-in frames.

## Wood door frame

Wood door frames are assembled from three members for internal doors and four to most external doors. The members of the frame are two side posts, a head and a sill for external doors where Regulations do not prohibit an upstanding sill which would obstruct access for the disabled in wheelchairs.

The members of the frame are usually cut with a rebate into which the door closes or a wood stop may be planted on a plain faced timber, as a door stop.

**Fig. 127** A Door frame. B Mortice and tenon joint.

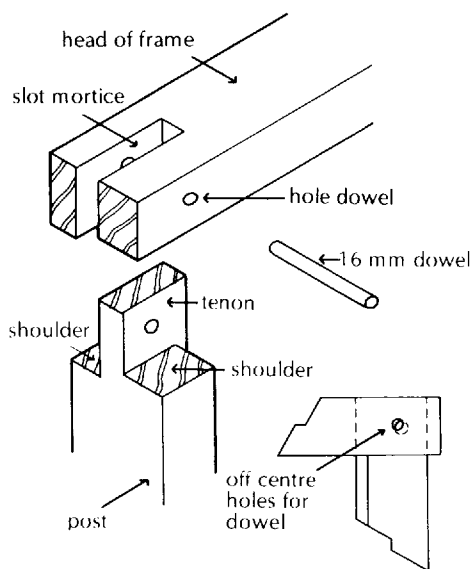


Because the frame is made to carry the weight of the door by itself, the members are joined with mortice and tenon joints to provide a rigid joint that will maintain the frame true square as illustrated in Fig. 127A. The haunched mortice and tenon joints between the posts and head of the door frame are formed as illustrated in Fig. 127A and in detail in Fig. 127B. The joint is formed by projecting the head of the frame some 100 mm each side of the posts as horns. These horns also provide a means of securing the frame by building them into surrounding brickwork where the frame is set at least  $\frac{1}{2} B$  back from the external face of the wall.

Where it is not convenient to build in horns when the door frame is fixed closed to the external face of a wall, the head is finished flush with the back of the posts. As it is not possible to form an enclosing mortice a slot mortice and tenon joint is formed as illustrated in Fig. 128. The tenon is secured in the slot mortice with a 16 mm dowel driven through the mortice and tenon.

To secure the foot of the posts of a door frame without a threshold it is usual to fix a steel dowel (rod) 12 mm diameter and 50 mm long, half into the foot of the frame and half into the concrete threshold.

Door frames to external walls are usually built-in. To maintain the



**Fig. 128** Slot mortice and tenon.

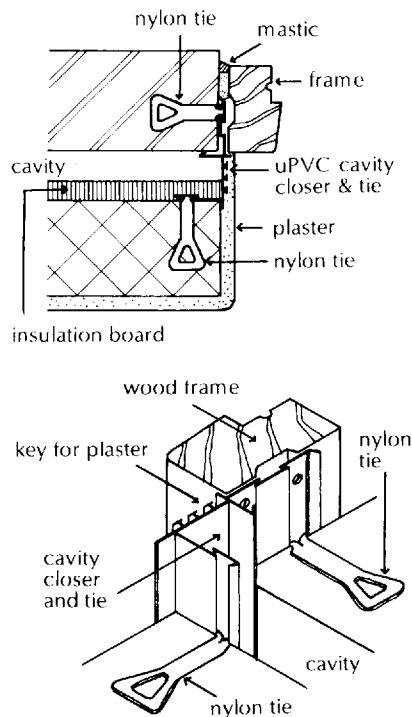


Fig. 129 uPVC cavity closer and tie.

## Threshold

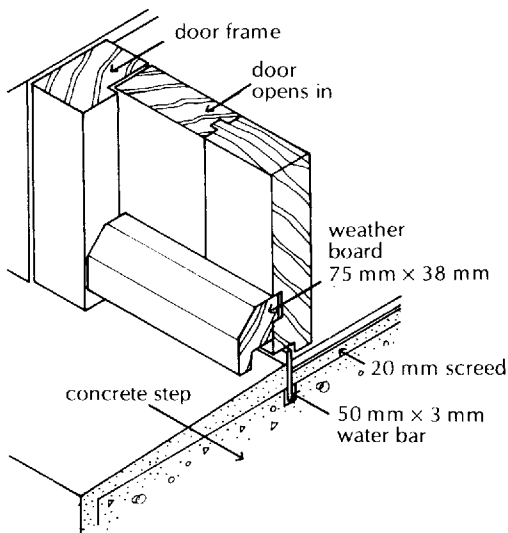


Fig. 130 Water bar and weatherboard.

frame in position against the frequent use of a front door and for reasons of security against forced entry, the frame is secured with building in lugs that are built into horizontal courses of brickwork or blockwork as the walls are raised.

The usual form of building in lug used to secure wood window and door frames in solid walls is 'L' shaped, formed from steel and galvanised. One tail of the lug is screwed to the back of the frame and the other is bedded in a horizontal brick or block course. Three lugs to each post are used.

Providing these lugs, illustrated in Fig. 127A, are solidly bedded in mortar they will adequately secure the frame in position.

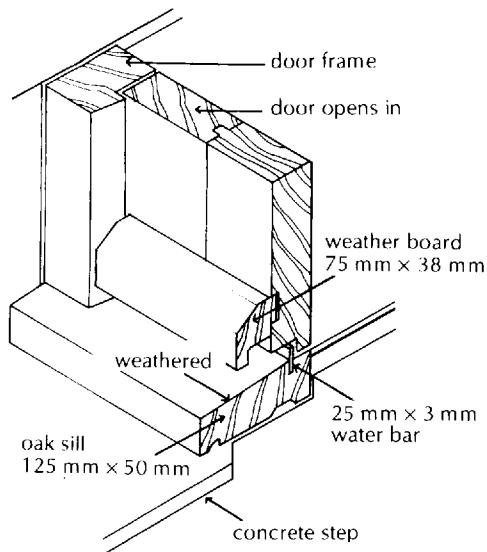
A uPVC cavity closer and ties, illustrated in Fig. 129, is designed to close the cavity of a wall and allow the cavity insulation to be carried up to the back of the closer, so that there is no thermal bridge around the openings and to provide secure fixing for a door frame through nylon ties. The cavity closer is nailed to the back of the frame and the nylon ties are adjusted in slots for building into horizontal brick or block courses as the frame is built-in.

The threshold of a doorway or opening is the surface at the bottom of the opening which is level for internal doors and may be level or formed as a wood sill as part of the door frame. A level threshold may be formed for ease of access for the disabled who have need of the use of a wheelchair. The considerable disadvantage of this is that there is no positive check to wind-driven rain that runs down the door face and will be blown in under the closed door.

As a barrier to wind-driven rain running in under a door, a galvanised steel weather or water bar may be set in the threshold to stick up sufficiently above the level of the threshold so that when the door is closed it makes contact with the bar as a seal against the entry of rain as illustrated in Fig. 130. To direct rain water out from the door a weatherboard of timber or metal is often fixed to the bottom of the door.

The disadvantage of the water bar is that it is of small section and not always obvious to the unwary who may trip over it.

The ground floor of many buildings, particularly houses, is usually finished above the level of the ground surface outside as a convenience in uniting the damp proof course in the walls with that under the solid floor. External doors are usually approached from outside by climbing one or more steps. It is common, therefore, to hang



**Fig. 131** Oak sill.

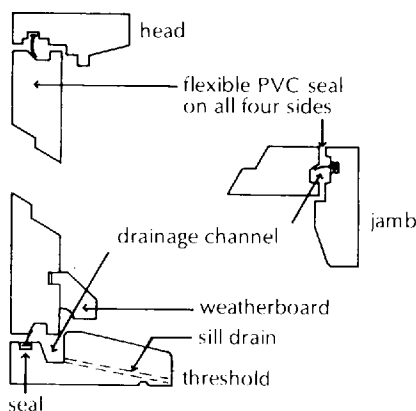
external doors to open inwards to avoid the danger of people hurrying out of externally opening doors and tumbling down the outside steps.

The disadvantage of an inward opening external door is that the rebate in the door frame, into which the door fits when closed, does not so positively act as a check to wind and rain as it does with an outward opening door. Wind pressure on an inward opening door may force it away from the rebate to the extent that wind and rain may penetrate.

The traditional external door frame was made up with a wood sill as part of the framing with the posts of the frame tenoned to mortices in the sill. The sill was often cut from oak for the sake of the durability of that hard wood. The oak sill, which is of a wider section than the posts, is weathered and cut with a drip on its lower edge to throw water off as illustrated in Fig. 131.

The sill may be rebated as housing for the door when closed or finished flush with the floor. A metal weather bar is set in the oak sill to stick up sufficient to fit into a rebate cut in the underside of the door as weather check. A wood weatherboard was usually fixed to the bottom of the outside of the door to throw rain out from the bottom of the door. Unless the protective paint film is well maintained over the door surface, the wood weatherboard will before long become saturated and rot. A range of aluminium sections is available for use as weatherboards.

## Weatherstripping

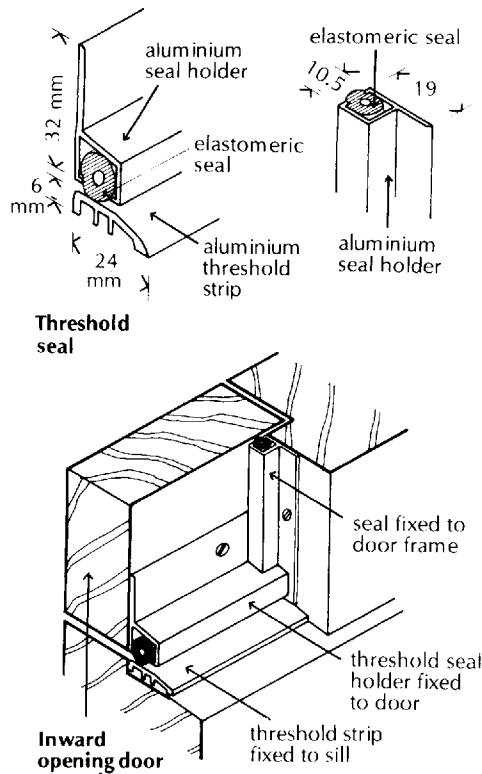


**Fig. 132** Inward opening external door with weather strips.

As a check to wind-driven rain and draughts of cold outside air that penetrate clearance gaps around external doors it is practice today to fit weatherstripping around doors to limit damage caused to wood doors by rain and heat loss to cold air. The two systems of weatherstripping that are used are flexible seals fixed towards the inside face and compression seals fixed up to the outside face of doors.

Flexible seals are made from PVC or synthetic rubber in the form of a strip for housing in the frame from which a flexible blade makes contact with the edges of the door. The seal may be fitted into an aluminium channel holder which is fixed into a groove cut in the frame. The flexible seal does not make it difficult to open or close the door, but is sufficiently resilient to make positive contact with the closed door.

The members of the door frame and door illustrated in Fig. 132 are cut with rebates to form a drainage channel up to the outer



**Fig. 133** Threshold and side weather seal to inward opening external door.

face of the flexible seals. This small channel serves the purpose of drainage channel and to reduce wind pressure on the flexible seal.

The synthetic rubber seals are similar to those described and illustrated for use with wood casement windows.

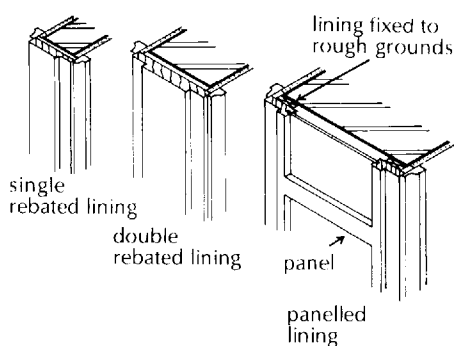
Compression seals consist of hollow ball section strips of synthetic rubber in an aluminium alloy holder. The holders are screwed or pinned to the head and posts of the door frame so that the elastic seal presses against the closed outside of the door as a weather seal.

The bottom edge of the door is sealed by a holder, fixed to the door, in which an elastic bulb presses on an aluminium alloy threshold strip fixed to the sill as illustrated in Fig. 133. Unlike the flexible blade weatherstripping these compression seals and their holders are visible, which may be unacceptable to some.

Both the flexible PVC blade strip and the compression seal bulb will after some years lose resilience and be less effective as seals. They should be replaced from time to time. When regular painting of doors and frame is carried out care should be taken to avoid painting over the blade seal and the compression seal as a dried, painted film will make them less effective.

As an alternative to the compression seals illustrated in Fig. 133 one of the self adhesive weatherstrips may be used.

## Wood door linings



**Fig. 134** Door linings.

Wood door linings (door casings) may be plain and rebated or plain with planted stops, double rebated for appearance sake or panelled as illustrated in Fig. 134.

Plain linings with either a rebate or a planted stop are used for light doors in thin partitions, double rebated linings for thicker brick or block partitions and panelled linings for heavier panelled doors in thicker walls or partitions.

Linings are fixed in position in the door opening before plastering to walls is carried out, so that the finished plaster level is flush with the edges of the lining. The linings are nailed to rough wood grounds. Rough grounds are sections of plain sawn wood that are nailed to the surrounding brick or block partition to provide a level fixing to which the lining is nailed. The purpose of this is to avoid damaging the lining by driving large nails through the lining to find a fixing in the brick or block partition.

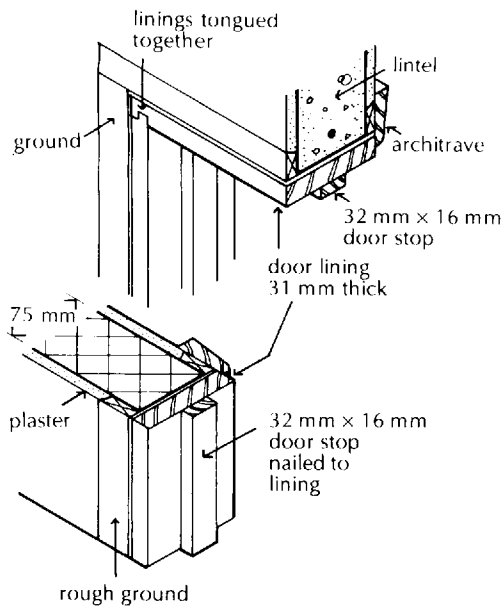


Fig. 135 Door linings.

## Standard door frames and linings

To provide a secure fixing for all but very narrow wood architraves around doors it is practice to fix rough, wood grounds each side of the lining and as thick as the plaster as illustrated in Fig. 135.

Linings are cut to the overall thickness of partitions and the thickness of plaster both sides. Plain linings are usually cut from timber 47 or 54 mm thick for rebated linings and 31 or 38 mm thick for linings with planted stops. Planted door stops effect some small economy in wood.

Figure 135 is an illustration of a plain lining with planted stops fixed to a partition. The sides of the lining are jointed to the head with a tongued and grooved joint to secure the three sections in position.

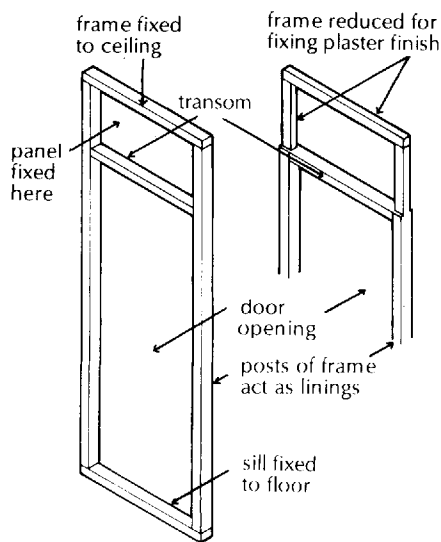
Door manufacturers offer a range of standard frames and linings for standard size doors. The door frames are cut from sections of  $102 \times 64$  mm and  $89 \times 64$  mm rebated for doors and with sills for external doors. Door linings, or casings as they are sometimes called, are cut from sections  $138 \times 38$ ,  $138 \times 32$ ,  $115 \times 38$  mm and  $115 \times 32$  mm rebated for doors. The width of these linings which is chosen to suit common partition and plaster thicknesses may not match the overall thickness of some partitions and finishes.

## Door sets

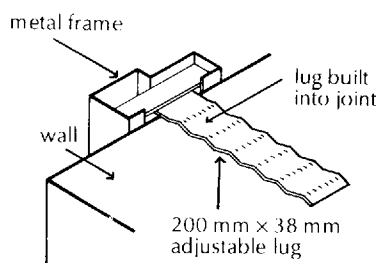
Door sets (door assemblies) are combinations of doors with door frames or linings and hardware such as hinges and furniture, prepared as a package ready for use on site. This plainly makes economic sense where many similar doors are to be used and packets of doors can be ordered and delivered instead of separately ordering doors, frames and hardware.

There is often inadequate fixing for a door frame or lining in a thin non-loadbearing partition so that the door, in use, may cause some movement in the frame or lining relative to the partition, to the extent that cracks in finishes around the frame or lining and particularly in the partition over the head of the door may appear. To provide a more secure fixing for doors in thin partitions it is often practice to use storey-height frames that can be fixed at floor and ceiling level.

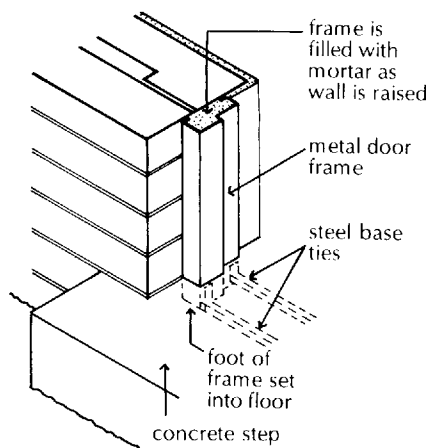




**Fig. 136** Storey height door frame.



**Adjustable building in lug for metal door frames**



**Fig. 137** Metal door frame.

These storey-height or floor-height frames are cut to line the reveal of the door opening and in that sense serve as linings, and are put together with floor-height posts, a head that can be fixed to the ceiling, a transom at the head of the door and also a sill for fixing to the floor, as illustrated in Fig. 136. The frame sections may be rebated for the door or be plain with planted stops. The frame may be of uniform width for the full height with a panel fixed in the space over the door, or the width of the frame may be reduced over the door so that finishes, such as plaster, may be run across the frame over the door.

The sill of the storey-height door frame may be fixed to the floor so that floor boards can be fixed over it or finished flush with the floor finish for carpeted finishes.

The advantage of these frames is that they provide a degree of stability to block, non-loadbearing partitions.

Metal door frames are manufactured from mild steel strip pressed into one of three standard profiles. The same profile is used for head and jambs of the frame. The three pressed steel members are welded together at angles. After manufacture the frames are hot-dip galvanised to protect the steel against corrosion. Two loose pin butt hinges are welded to one jamb of the frame and an adjustable, lock strike plate to the other. Two rubber buffers are fitted into the rebate of the jambs to which the door closes to cushion the impact of sound of the door closing. Figure 137 is an illustration of a standard metal door frame. The frames are made to suit standard door sizes. The frames are provided with steel, base ties welded across the foot of the posts of the frame to maintain the correct spacing of the posts.

Metal door frames are built-in and secured with adjustable, metal building-in lugs that are bedded in the horizontal joints of brick or blockwork, three to each side. The frames are bedded in mortar and filled with mortar.

These frames are made to suit standard external and internal wood doors. When used for internal doors in non-loadbearing partitions a profile of metal frame is selected that is wider than the combined thickness of the partition and plaster both sides. In this way the metal frame serves as a door lining that projects some 16 mm each side of the finished plaster. Plaster is run up to and under the lipped edges of the frame to avoid the necessity for an architrave to mask the junction between plaster and frame.

## METAL DOORS

### Glazed steel doors

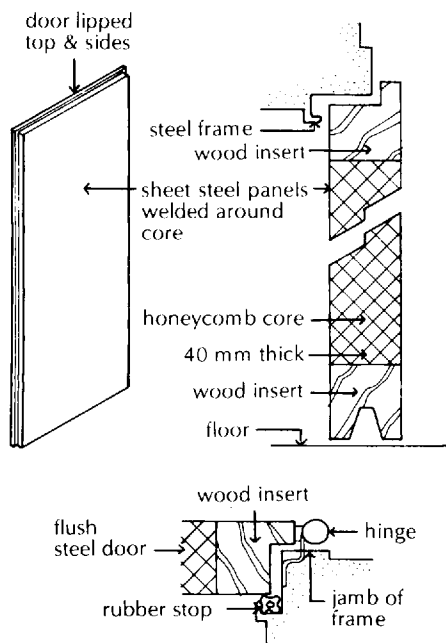


Fig. 138 Flush steel door.

Glazed steel doors are fabricated from the hot rolled W20 steel sections used for windows. The sections are assembled with welded corner joints. The doors and frames, which are hot dip galvanised after manufacture, may be finished with an organic powder coating. Single glass is either putty or clip-on aluminium bead glazed. Double glazing is bedded in mastic tape and secured with clip-on aluminium beads. Glazed steel doors, which have largely been superseded by aluminium doors, are mainly used for replacement work.

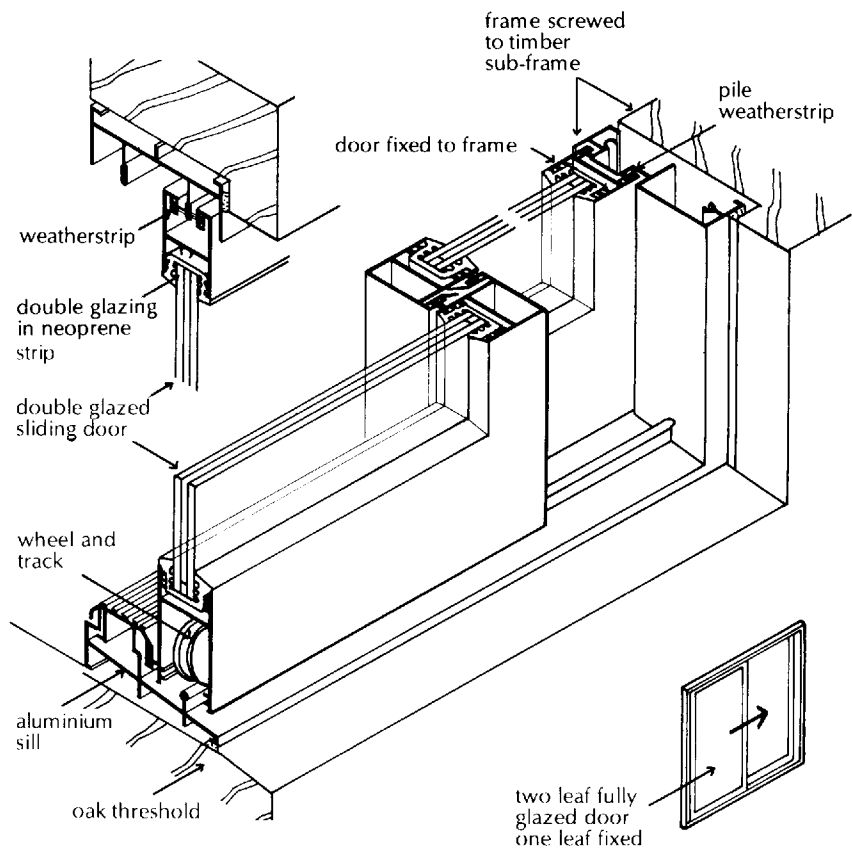
Flush steel doors are manufactured from sheet steel which is pressed to shape, often with lipped edges, hot dip galvanised and either seam welded or joined with plastic, thermal break seals around a fibre board, chip board or foamed insulation core, generally with edge, wood inserts as framing and to facilitate fixing of hardware. The sheet steel facings may be flush faced or pressed to imitate wood panelling or with glazed panels. The exposed faces of the doors may be finished ready for painting or with a stoved on organic powder or liquid coating.

These comparatively expensive, robust, heavy duty doors are generally used in this country in commercial and industrial buildings and as fire doors. In North America and parts of Northern Europe they are extensively used in all types of buildings. These doors are generally supplied as door sets complete with frame, door leaf and hardware fittings. Figure 138 is an illustration of a flush faced steel door.

## ALUMINIUM DOORS

An extensive range of partly-glazed and fully-glazed doors is manufactured from extruded aluminium sections. The slender sections possible with the material in framing the doors provide the maximum area of glass. These glazed doors, commonly advertised as 'patio doors', are made as both single and multi-leaf doors to hinge, slide or slide and fold to open. Glazed doors serve as a window by virtue of the large area of glass which provides no privacy, and as doors by the facility to open them from floor level. As windows they afford little insulation against loss of heat, unless double glazed, and as doors give poor security because of the extensive use of glass. The particular use of these doors is to provide a large area of clear glass for an unobstructed view out to gardens and to give ready access from inside to outside.

Figure 139 is an illustration of an aluminium section glazed door designed to slide open. The doors are double glazed to reduce heat loss and have weatherstripping and drainage channels to exclude wind and rain.



**Fig. 139** Fully glazed aluminium horizontally sliding door.

A disadvantage of these doors is that there may be appreciable condensation on the inside faces of the aluminium framing. To minimise condensation on the inside faces of these double glazed doors it is practice to fabricate them as thermal break doors. The main framing sections of the doors, which are joined with corner cleats, are fixed to aluminium facings through plastic sections that act as a thermal break.

Of recent years single-leaf aluminium doors have been made to resemble traditional panelled wood doors. These, so called, residential doors are framed from extruded aluminium sections in the same way that windows and fully glazed doors are fabricated with the addition of a middle, horizontal rail to imitate the middle or lock rail of a wood door. The sections are made to take either glazed or solid panels secured with internal pop-in glazing beads. The solid panels, which are fabricated from PVC or glass fibre reinforced plastic sheets around an insulating core, may be moulded to imitate traditional wood panels.

An advantage of these doors is that they may be finished in a range of coloured powder or liquid coatings that do not require periodic painting for maintenance. These doors are sufficiently robust for use in domestic buildings and may be fabricated as thermal break

construction to minimise condensation on the internal faces of the aluminium framing.

These residential, aluminium doors do not look like the traditional panelled wood doors they are made to replicate and may be a poor security risk unless the panels are reinforced with an aluminium sheet in the core and the panels are fixed with screwed or secured beads.

## uPVC DOORS

Following the success of uPVC windows as replacement for wood windows, the extruders and fabricators of uPVC sections have in the last few years produced single-leaf uPVC doors for replacement or substitution of traditional panelled wood doors. These doors are fabricated from a frame of comparatively bulky, extruded uPVC hollow sections similar in size to the stiles and rails of wood framed doors. The hollow framing sections are reinforced with galvanised steel or aluminium sections in the main cell of the hollow sections that are mitred and heat fusion welded at corners. A mid rail member is fitted to match the middle or lock rail of a wood door. These door leafs are hung to extruded, hollow section uPVC frames and thresholds as illustrated in Fig. 140.

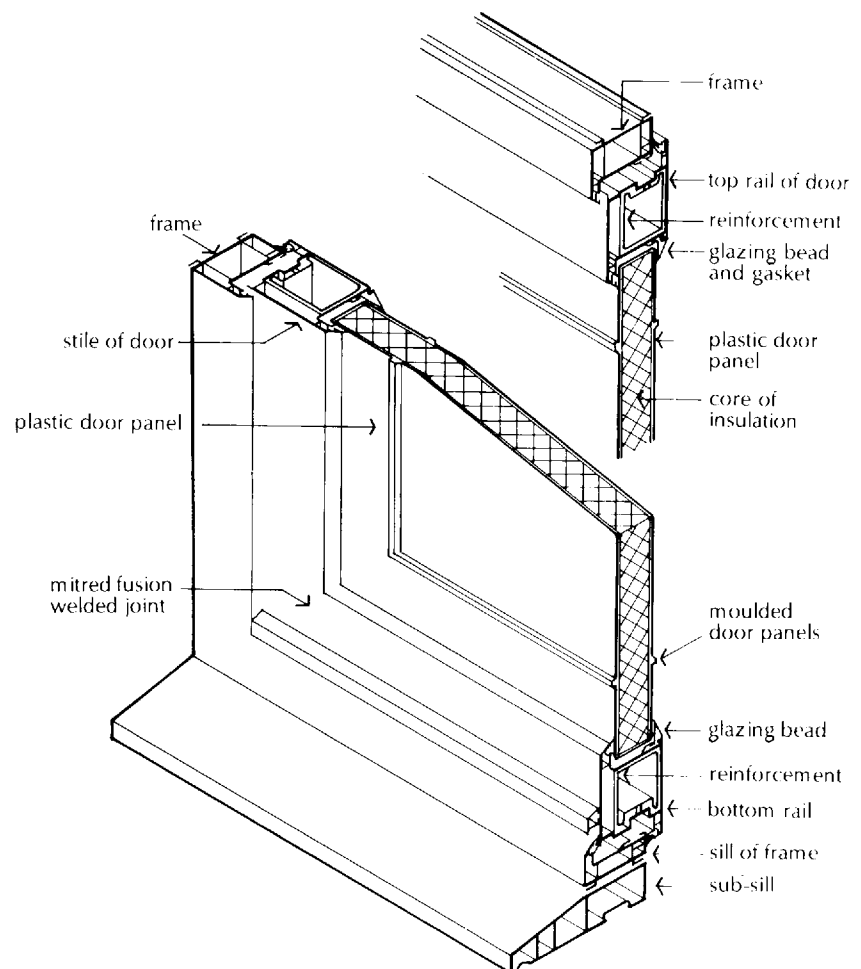


Fig. 140 uPVC door and frame.

The uPVC door leafs which are framed for glazing with single or double glazing secured with internal pop-in beads are weathered with wedge and blade gaskets. As an alternative to glazed panels a variety of plastic panels is produced from press moulded acrylic, generally moulded to imitate wood door panels either as full door height panels or as two panels fitted to a middle rail. The panels which have plain edges for fitting to the rebate and glazing beads of the hollow uPVC framing, are moulded to represent the stiles, rails and panels of wood doors. In consequence these doors do not look like the panelled wood doors they are fabricated to replicate.

The hollow panels may have a core of some insulating material and a foil or thin sheet of aluminium as a barrier to breaking and entering by fracturing the panel.

The majority of these doors are made as white or off white impact modified uPVC to minimise the considerable thermal expansion that this material suffers due to solar radiation. Coloured and wood grain finishes are also supplied.

The advantage of uPVC doors is that they require no maintenance during their useful life, other than occasional washing. The disadvantage of these doors is that they may jam shut due to thermal expansion, knocks and indentations cannot be disguised by painting and they are not as robust to heavy use as a traditional wood framed door.

Pressed metal doors are suited for use as garage doors because they are lightweight and have adequate stiffness and shape stability for a balanced 'up-and-over' opening action. The doors are manufactured from pressed steel or aluminium sheet which is profiled to give the thin sheet material some stiffness. The sheet is welded or screwed to a light frame to give the door sufficient rigidity. Steel doors are hot-dip galvanised and primed for painting or coated with PVC, and aluminium doors are anodised. Figure 141 is an illustration of a steel up-and-over garage door.

To open, the door is lifted to slide on wheels in overhead tracks under the roof of the garage. Spring loaded side stays attached by pivots to the base of the door serve to steady the upward and downward movement of the door leaf and serve to balance the movement so that it may easily be raised and lowered by hand. The advantage of the overhead action is that the door does not obtrude on the outside.

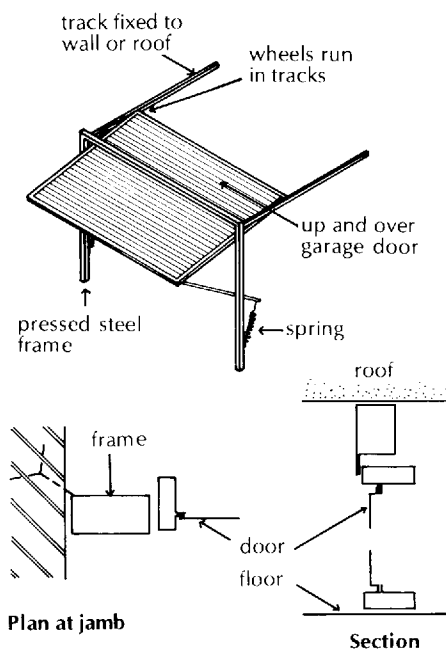
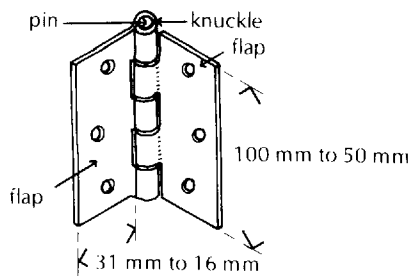


Fig. 141 Steel 'up-and-over' garage door.

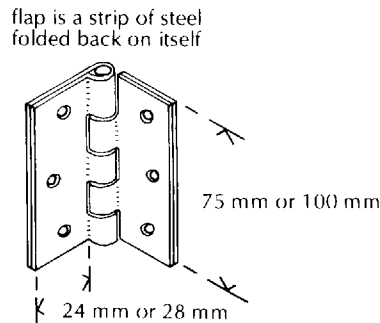
## HARDWARE FOR DOORS

Hardware is the general term for the hinges, locks, bolts, latches and handles for a door. Ironmongery was a term used when most of these were made of iron or steel. The term 'door furniture' is sometimes used to describe locks, handles and levers for doors.

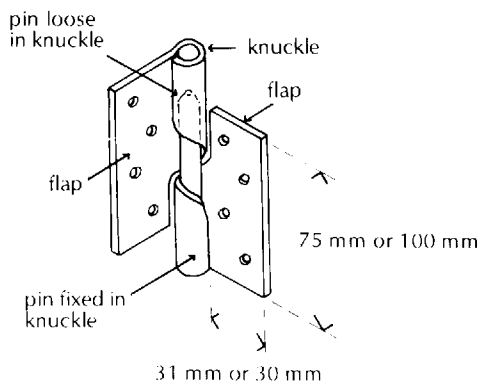
Pressed steel butt hinges are the cheapest and most commonly used



**Fig. 142** Pressed steel butt hinges.



**Fig. 143** Double pressed heavy steel butt hinge.



**Fig. 144** Steel skew butt hinge (rising butt hinge).

hinges. They are made from steel strip which is cut and pressed around a pin, as illustrated in Fig. 142. They are used for hanging doors, casements and ventlights. The pin of the standard butt hinge is fixed inside the knuckle.

These hinges are also made as loose pin butt hinges, with the flap, that is screwed to the edge of the door, loose inside the knuckle so that the doors can be taken off by lifting. This avoids the necessity of unscrewing one flap of each hinge to take the door off for adjustment and for repair. These hinges are usually galvanised as protection against corrosion.

The two flaps of the hinge are screwed in position into shallow sinkings cut in the wood frame and edge of the door respectively so that they are flush with the wood faces and with the knuckle of the hinge protruding from the face of the door.

Double pressed, heavy, steel butt hinges are made of two strips of steel each folded back on itself as a flap and pressed and cut to form the knuckle around the pin as illustrated in Fig. 143. Because of the double thickness of steel strip from which they are made, these hinges serve as heavy duty to support larger, thicker doors.

The traditional hinges for panelled doors were made of cast iron. The comparatively thick section of the cast iron butts and knuckle, folded around a pin, was strong enough to carry the weight of the heaviest panelled door. An advantage of the cast iron from which these hinges are made is that it does not progressively and destructively rust as does mild steel and a disadvantage that the metal is brittle and liable to crack.

These comparatively expensive hinges are less used today other than for external doors.

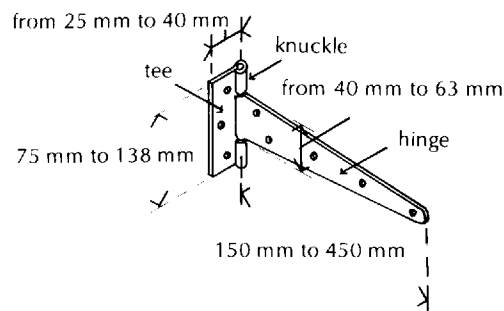
The bearing surfaces of the knuckle of both flaps of the rising butt hinge are cut on the skew so that as the hinge opens one flap rises, as illustrated in Fig. 144. Because of the action of the hinge, as it opens, these hinges are generally described as 'rising butt hinges'.

These hinges are used for hanging doors so that as the door opens it rises over and so clears such floor coverings as fitted carpets to reduce wear.

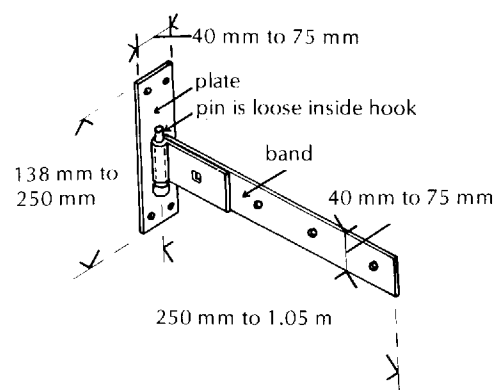
The action of the skew butt will tend to make the weight of all but the lightest doors, self closing.

Steel tee hinges comprise a rectangular steel flap and a long tail or hinge which are pressed around a pin as knuckles. The form of the hinge gives it its name.

These hinges are made for use with matchboarded doors and garage and other wide doors where the length of the long tail of the



**Fig. 145** Steel tee hinge.



**Fig. 146** Hook and band hinge.

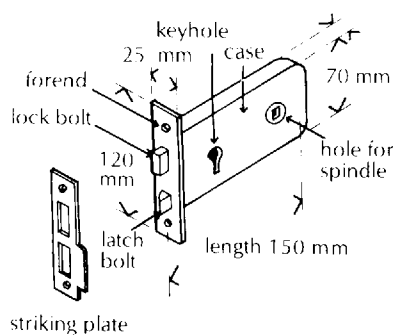
## Latches and locks

The word latch is used to describe any wood or metal device that is attached to a door or window to keep it closed. The latch consists of a plain bar of wood or metal which is attached to a door or gate and is pivoted so that it can be raised by hand above a hook or keep attached to the door or window frame. These simple, crude devices serve the purpose of keeping the door or window in the closed position. They do not lock the door.

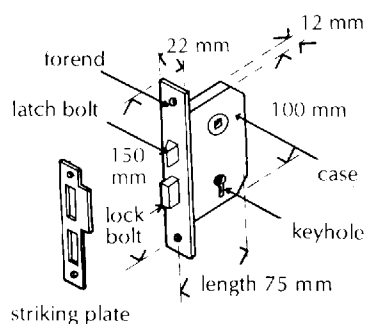
A lock is any device of wood or metal which is attached to a door or window to keep it closed by the operation of a bolt that moves horizontally into a striking plate or staple fixed to the door or window frame. Most locks are made of steel or brass and combine the operation of keeping doors and windows closed with a latch bolt operated by a handle or lever and keeping doors and windows securely shut by the operation of a loose key to move a lock bolt.

## Mortice lock

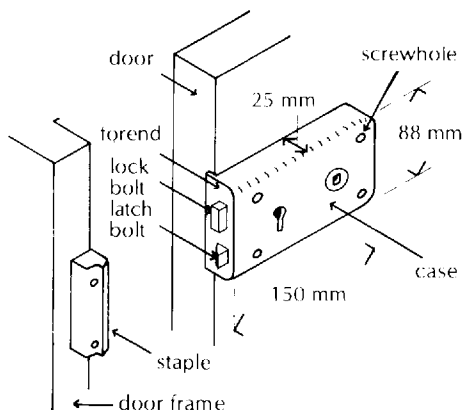
The mechanism most used today for doors is the mortice lock, so called because the metal case containing the operating parts is set into a mortice cut in the door. Locks for external doors and internal doors, where security is a consideration, consist of a latch bolt and a lock



**Fig. 147** Horizontal two bolt mortice lock.



**Fig. 148** Upright two bolt mortice lock.



**Fig. 149** Horizontal two bolt rim lock.

## Mortice dead lock

bolt. For internal doors in continuous use the locks contain a single latch bolt to keep the door closed.

A mortice lock for an external door is set inside a mortice cut in the stile and middle rail of the door. The horizontal, two bolt mortice lock, illustrated in Fig. 147, consists of a case, a forend and a striking plate. The case fits into a mortice in the door through which holes have been drilled for a loose key and for the spindle for knobs or handles. The lock may be made with a forend plate that is screwed into position flush with the edge of the door or finished with a forend and cover plate of brass for appearance sake.

A striking plate is fixed over mortices cut in the door frame to house the two bolts. This plate is termed a striking plate, as it serves the purpose of directing the shaped end of the latch bolt into the plate as the door is shut.

For flush doors and those without a middle rail an upright two bolt mortice lock is used. The lock, illustrated in Fig. 148, is designed specifically for this use.

Two bolt mortice locks are supplied with two loose keys to operate the lock bolt. Knobs, lever handles and a spindle are supplied separately from the locks to which they are fitted, as what is sometimes described as 'door furniture'.

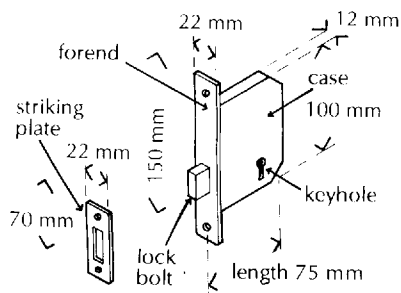
Single bolt mortice locks which are supplied for internal doors comprise a case, forend and striking plate with one latch bolt which is operated by knobs or lever handles and a spindle. As they do not lock the door, these devices should properly be called latches.

Light duty internal doors which are often too thin to accommodate a mortice lock may be secured with a rim lock. These locks are designed for fixing to the face of doors. The case and the forend are screwed to the face of the door as illustrated in Fig. 149. The latch bolt and lock bolt fit into a metal staple fixed to the face of the door frame with the staple shaped to guide the latch bolt into position as the door is closed. Rim locks may be single bolt as latches or two bolt for security.

Because of their somewhat clumsy appearance these locks are not much used. As they are usually fixed to comparatively flimsy doors which themselves offer poor security, there does not seem too much sense in using a two bolt rim lock other than for the sense rather than the reality of security.

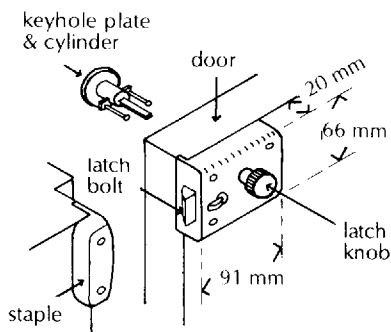
A mortice dead lock consists of a single bolt which is operated by a loose key. There is no latch bolt. It is a dead lock in the sense that once the bolt is shot, moved into the closed position, and the key removed it is dead to being operated. These locks are used in conjunction with and separate from a cylinder night latch for security.





**Fig. 150** Mortice dead lock.

### Cylinder rim night latch (springlatch)



**Fig. 151** Cylinder rim night latch.

The upright case is housed in a mortice cut in the stile of the door and screwed through the forend to the edge of the door. The lock bolt is shot, closed, into a lock plate screwed over a mortice cut in the door frame. Figure 150 is an illustration of a typical dead lock.

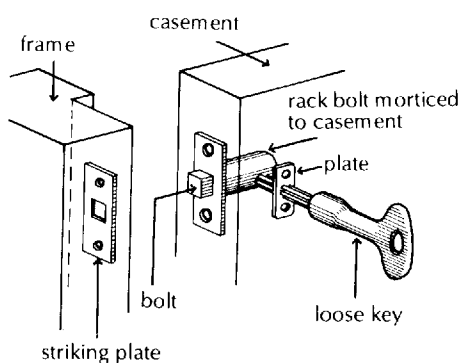
The security of this locking device depends to an extent on the number of so called levers that are operated by the key. The greater the number of levers the greater the security. This type of lock may be used for both wood doors and wood casement windows where the stile of the casement is wide enough to house the lock case.

A cylinder night latch is designed to act as a latch from inside and a lock from outside for convenience in use on front doors. It is made as a rim latch for fixing to the inside face of doors (Fig. 151). There is one bolt, shaped as a latch for convenience in closing, which is opened by a knob or lever from the inside. For security the latch bolt can only be opened with a loose key from outside. This type of latch offers poor security as it is fairly easy to push back the latch from outside by means of a piece of thin plastic or metal inserted between the door and frame.

A more secure type of night latch is designed as a mortice lock which is opened as a latch from inside by means of a lever and from outside by a loose key. The lock has a double throw action which, by two turns of the key from outside, locks the latch in position so that it cannot be pushed back from outside.

As it is the most convenient means of keeping external front doors closed by use of a latch bolt and offers some small security through its operation of opening from outside by a loose key, this lock is much favoured. It should be used in conjunction with a mortice lock to entrance doors to houses and flats.

### Rack bolt



**Fig. 152** Rack bolt for security for wood windows and doors.

A rack bolt is a single locking device used for locking wood doors and casement windows. It consists of a cylindrical case and bolt which is fitted into a mortice cut in the stile of doors and casements of windows as illustrated in Fig. 152. The bolt is operated by a loose key from inside the door or window.

The bolt is fitted to a mortice in the door or window and the forend screwed to a shallow housing in the door or window edge. A striking plate is fixed over a mortice in the frame and screwed in position in a shallow housing.

Two of these rack bolts fitted top and bottom to doors and casements or one to small casements serve as an economical and very effective means of locking shut.

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## 3: Stairs

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For access between floors and different levels in buildings a ladder, stair or ramp is used.

### Ladders

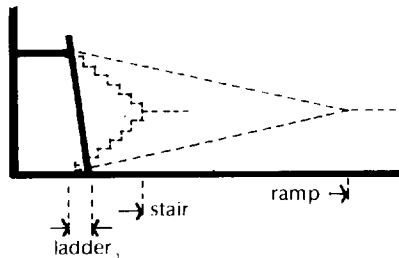


Fig. 153 Ladder.

A ladder is made as a series of narrow horizontal steps (rungs), fixed between two uprights of wood or metal, on which a person usually ascends (climbs up) or descends (climbs down) facing the ladder. A ladder may be fixed in an upright, vertical position or more usually at a shallow slope to the vertical for ease of use. Because a ladder is fixed near vertical it occupies the least floor area of any of the three means of access between floors as illustrated in Fig. 153.

Because it is fixed near vertical it is necessary to hold on to a ladder for safety, which makes it unsuitable for the very young, elderly and handicapped and as a means of escape in case of fire.

Approved Document K to the Building Regulations recommends that a ladder should only be used for access to a loft conversion of one room, where there is not enough space for a stair, and that the ladder be fixed in position and fitted with handrails both sides.

### Stepladders

A stepladder consists of a series of comparatively narrow, flat, horizontal steps, fixed between two vertical uprights, which provide a more comfortable and secure support for the foot than the slim, usually round rungs of a ladder.

### Stairs

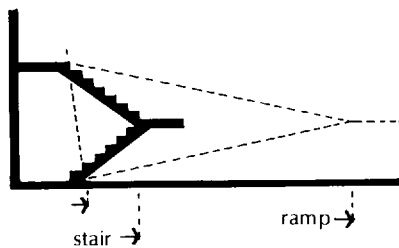


Fig. 154 Half turn stair.

A stair, or stairway, is the name given to a set of steps formed or constructed to make it possible to pass to another level on foot by putting one foot after the other on alternate steps to climb up or down the stair.

A stair may be formed as a series of steps rising in one direction between floors as a straight flight of steps. More usually a stair is formed as two or more straight flights of steps arranged to make a quarter or half turn at intermediate landings between floors to limit the number of steps in each flight for safety in use.

Because of the slope of the stair and the need to limit the number of steps in each flight a typical half turn stair occupies a considerable space in small houses as illustrated in Fig. 154.

### Ramps

A ramp is a surface, sloping uniformly as an inclined plane up and down which a person may pass on foot between levels. A ramp is formed or constructed at a slope of at least 1 in 20 (1 m rise vertically in 20 m horizontally). Because of the comparatively shallow slope of a

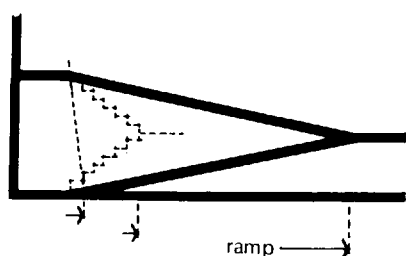


Fig. 155 Ramp.

ramp it occupies a considerable area as illustrated in Fig. 155, and is best suited to long low buildings as an adjunct.

A stair is the conventional means of access between floors in buildings. It should be constructed to provide ready, easy, comfortable and safe access up and down with steps that are neither laborious nor difficult to climb, within a compact area, so as not to take up excessive floor space.

The minimum dimensions for stairways are set out in Approved Document K giving practical guidance to meeting the requirements of the Building Regulations.

The functional requirements of a stair are:

Strength and stability  
Safety in use  
Fire safety

## FUNCTIONAL REQUIREMENTS

### Strength and stability

A stair and its associated landings serves much the same function as a floor in the support of the occupants of a building, with the stepped inclined plane of flights serving as support for movement between floors. The requirements for strength and stability in supporting dead and imposed loads for floors apply equally to stairs.

### Safety in use

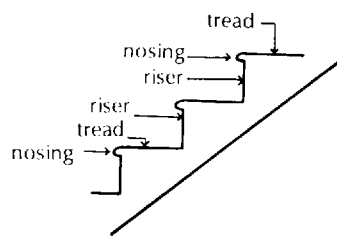
The practical guidance in Approved Document K to the Building Regulations is concerned with the safety of users in determining the rise, going and headroom of stairs and the dimensions of handrails and guarding.

### Fire safety

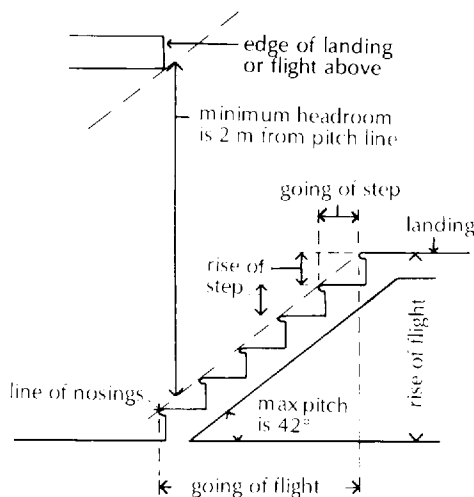
Stairs are the principal means of escape to the outside in case of fires in buildings. A stair should be constructed of materials that are capable of maintaining strength and stability for a period of time sufficient for those in a building to escape to the outside. The size of the steps and the width of the stair should be adequate for the safe escape of those in the building.

### Flight

The word flight describes an uninterrupted series of steps between floors or between floor and landing, or between landing and landing. A flight should have no fewer than three and no more than 16 risers in it otherwise it might be dangerous, particularly for the young or elderly. The rise and going of each step in one flight and in flights and landings between floors should be equal. Variations in the rise of steps will interrupt the rhythm of going up or down, may trip people and be dangerous. The usual unobstructed width of a flight is from 800 mm for houses to 1000 mm for other buildings.



**Fig. 156** Tread, riser and nosing of steps.



**Fig. 157** Rise, going and headroom for stairs.

The steps of a stair may be constructed as a series of horizontal open treads with a space between the treads or as enclosed steps with a vertical face between the treads, called a riser.

The horizontal surface of a step is described as the tread and the vertical or near vertical face as the riser. A stair which is constructed with horizontal treads with a space between them is often described as an open riser stair.

From 25 October 1999 reference should be made to Approved Document to Part M for stair dimensions for access for disabled people.

With enclosed steps the treads usually project beyond the face of the riser as a nosing to provide as wide a surface of tread as practicable. Figure 156 illustrates the use of the terms tread, riser and nosing.

The word rise describes the distance measured vertically from the surface of one tread to the surface of the next or the distance from the bottom to the top of a flight. The word going describes the distance, measured horizontally, from the face of the nosing of one riser to the face of the nosing of the next riser, as shown in Fig. 157. The dimensions of the rise and going of steps determine whether a stair is steep or shallow.

In Approved Document K to the Building Regulations the recommended rise and going for stairs is:

Private stair for one dwelling.

Any rise between 155 mm and 220 mm maximum used with any going between 245 mm and 260 mm or

Any rise between 165 mm and 200 mm used with any going between 223 and 300 mm

Institutional and assembly stair serving a building where a substantial number of people are gathered.

Any rise between 135 mm and 180 mm maximum used with any going between 280 mm minimum and 340 mm.

Other stairs in all other buildings.

Any rise between 150 mm and 190 mm maximum used with any going between 250 mm minimum and 320 mm.

The steeper stair is accepted for houses because the occupants are familiar with the stair and a shallow stair would occupy more area on plan and thus reduce the available living area. The

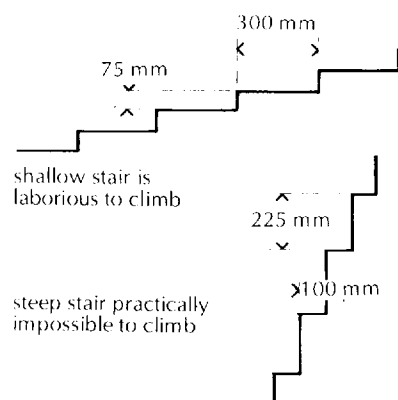


Fig. 158

## Head room

shallower a stair the more risers are required for a given height and therefore the more treads and greater plan area occupied by the stair. The shallow stair recommended for public buildings is designed to minimise danger to the public escaping via the stairs during emergency.

Where a stair is appreciably more shallow or steep than those recommended in Approved Document K as illustrated in Fig. 158, it would be laborious or practically impossible to climb.

The inclination of a stair can be described either by the rise and going of the steps or as the pitch of the stair, which is the angle of inclination of the stair to the horizontal, as illustrated in Fig. 157. Stairs are pitched at not more than  $42^\circ$  for stairs to single dwellings and not more than  $38^\circ$  for common stairs.

For people and for moving goods and furniture a minimum head room of 2 m, measured vertically, is recommended between the pitch line of the stair and the underside of the stairs, landings, and floors above the stair as illustrated in Fig. 157.

Before standards were set for the rise and going of steps it was practice to determine the pitch of a domestic stair from the simple formula: twice rise plus going equals some notional figure, between 550 and 700 mm, where an assumption of some convenient rise was made.

To set out a stair it is necessary to select a suitable rise and adjust it, if necessary, to the height from floor to floor so that the rise of each step is the same, floor to floor, and then either select a suitable going or use the formula  $2R + G = \text{between 550 and 700 mm}$  to determine the going.

The three basic ways in which stairs with parallel treads are planned are illustrated in Fig. 159. These are:

- A straight flight stair
- A quarter turn stair
- A half turn stair

## TYPES OF STAIR

### Straight flight stair

A straight flight stair, illustrated in Fig. 159, rises from floor to floor in one direction with or without an intermediate landing, hence the name straight flight. A straight flight stair, sometimes called a cottage stair, was commonly used in the traditional 'two-up two-down' cottage with the stair in the centre of the plan running from front to back giving access to the two upper rooms each side of the head of the stair, with access to the two ground floor rooms from the small hall at

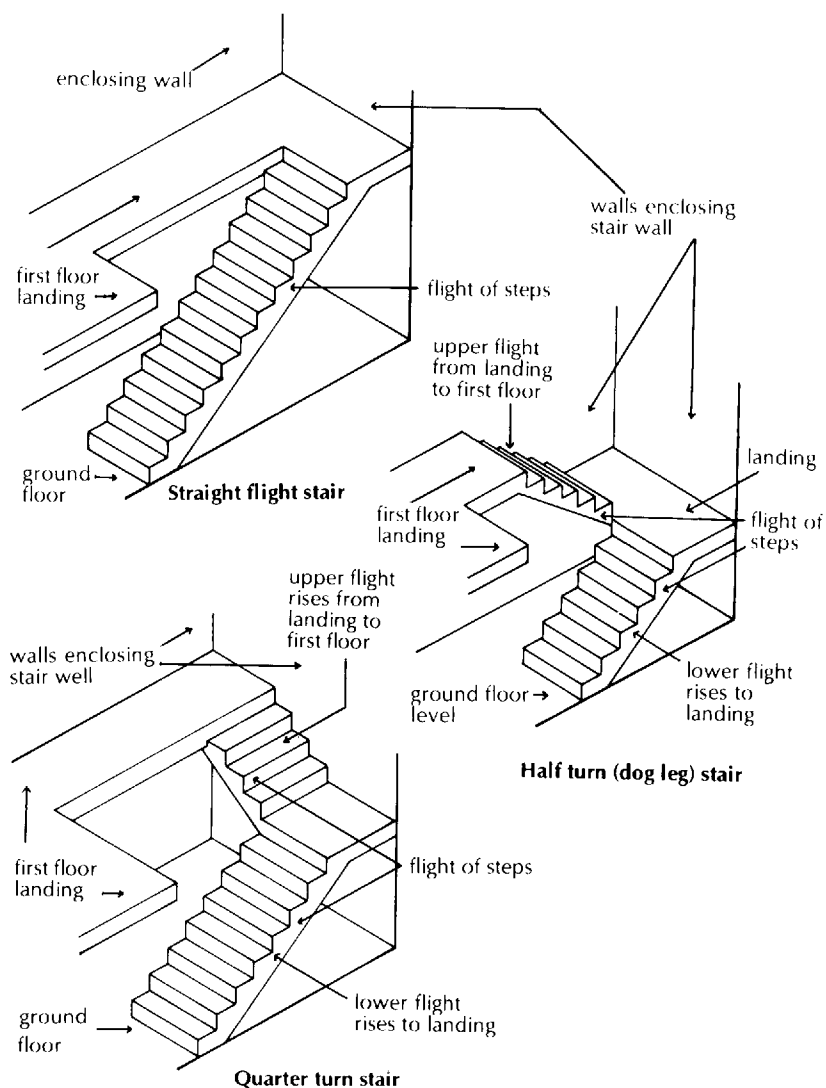


Fig. 159 Stairs.

the foot of the stair. This, the most economical use of the straight flight, does rigidly determine access to the rooms top and bottom if wasteful landings are to be avoided.

### Quarter turn stair

A quarter turn stair rises to a landing between two floors, turns through  $90^\circ$ , then rises to the floor above, hence 'quarter turn'. This type of staircase was much used in the two floor semi-detached houses built in the first half of the twentieth century, for its great economy in compact planning. The quarter space or quarter turn landing shown in Fig. 159 was often replaced with winders for further economy in the use of space.

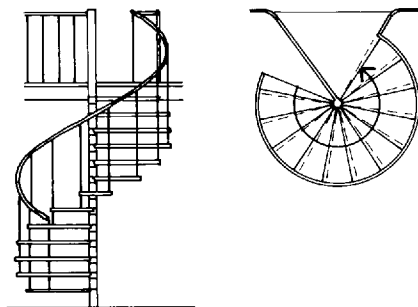
## Half turn, dog leg stair

A half turn stair rises to a landing between floors, turns through  $180^\circ$ , then rises parallel to the lower flight to the floor above, hence 'half turn'. The landing is described as a half space or half turn landing. A half turn stair is often described as a 'dog leg' stair because it looks somewhat like the hind leg of a dog in section. This, the most common arrangement of stairs, has the advantage in planning that it lands at, or roughly over, the starting point of the stair which can be constructed within the confines of a vertical stair well, as a means of access to and escape from similar floors.

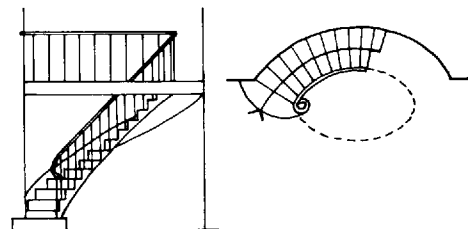
## Stair well

Stairs are sometimes described as 'open well stairs'. The description refers to a space or well between flights. A half turn or dog leg stair can be arranged with no space between the flights or with a space or well between them and this arrangement is sometimes described as an open well stair. A quarter turn stair can also be arranged with a space or well between the flights when it is also an open well stair. As the term 'open well' does not describe the arrangement of the flights of steps in a stair, it should only be used in conjunction with the more precise description straight flight, quarter or half turn stair (e.g. half turn stair with open well).

## Geometrical stairs



Spiral (helical) stair



Elliptical stair

Geometrical stairs are constructed with treads that are tapered on plan, with the tapered treads around a centre support as a spiral (helical) stair, an open well circular stair or as an ellipse or part of an ellipse or plan as illustrated in Fig. 160.

A spiral (helical) stair with the treads tapering to a central, vertical support is the most economical way of planning a stair as it takes up little floor area. Because the treads taper sharply to the central post and the need to make sharp turns up and down this type of stair it is difficult to use and may be dangerous to the very young or elderly. Spiral stairs, which form a helix around a central column or post, are used where space is limited for access to an intermediate floor of one room. A spiral stair is illustrated in Fig. 160.

Circular or elliptical stairs are constructed around a generous open well with the treads having a shallow taper towards the well. These stairs, which are extravagant in the use of space, are used as a feature for grand means of access in large buildings. An elliptical stair is illustrated in Fig. 160.

Stairs may be constructed of timber, stone, reinforced concrete or metal, with timber and stone being the traditional materials used before the advent of steel and reinforced concrete following the industrial revolution.

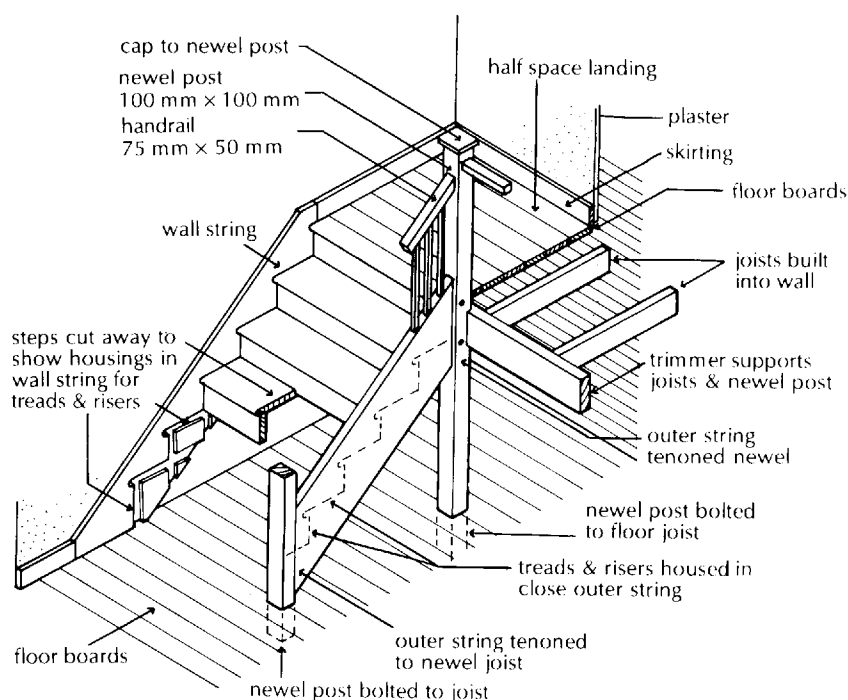
Fig. 160 Geometrical stairs.

## TIMBER STAIRCASE

A staircase, which is a stair with treads and risers constructed from timber boards put together in the same way as a box or case, hence the term staircase, is the traditional stair for houses of two or more floors where the need for resistance to fire does not dictate the use of concrete.

Each flight of a staircase is made up (cased) in a joiner's shop as a complete flight of steps, joined to strings. Landings are constructed on site and the flight or flights are fixed in position between landings and floors. The members of the staircase flight are string (or stringers), treads and risers. The treads and risers are joined to form the steps of the flight and are housed in, or fixed to, strings whose purpose is to support them. Because the members of the flight are put together like a box, thin boards can be used and yet be strong enough to carry the loads normal to stairs. The members of the flight are usually cut from timbers of the following sizes: treads 32 or 38 mm, risers 19 or 25 mm and strings 38 or 44 mm.

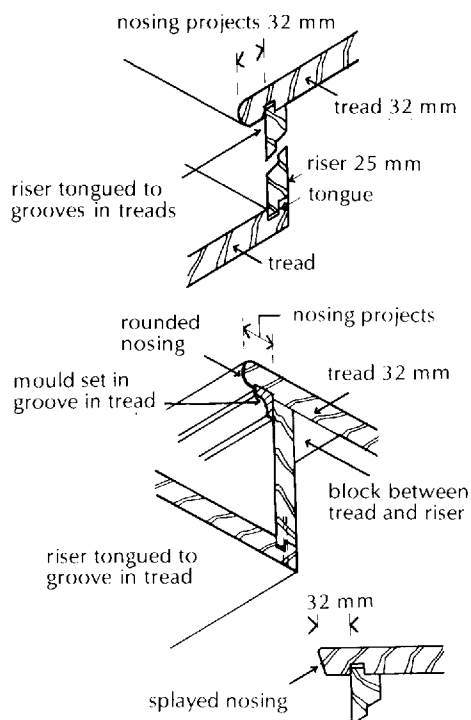
Figure 161 is an illustration of a flight of a staircase with some of the treads and risers taken away to show the housings in the string into which they fit and the construction of a landing.



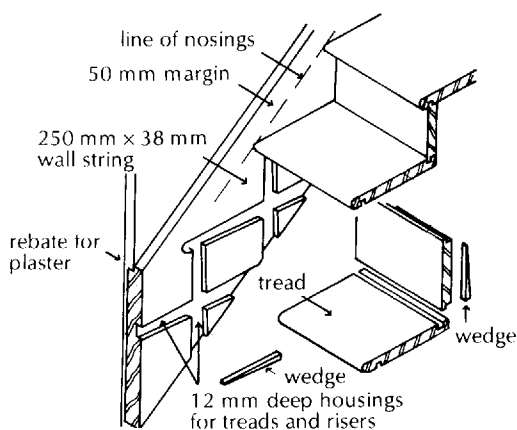
**Fig. 161** Lower flight of half turn staircase.



## Joining risers to treads



**Fig. 162** Method of jointing risers to treads



**Fig. 163** Housing treads and risers in close string.

The usual method of joining risers to treads is to cut tongues on the edges of the risers and fit them to grooves cut in the treads, as illustrated in Fig. 162. Another method is to butt the top of the riser under the tread with the joint between the two, which would otherwise be visible, masked by a moulded bead housed in the tread, as illustrated in Fig. 162. The tread of the stair tends to bend under the weight of people using it. When a tread bends, the tongue on the bottom of the riser comes out of the groove in the tread and the staircase 'creaks'. To prevent this it is common practice to secure the treads to the risers with screws (Fig. 162).

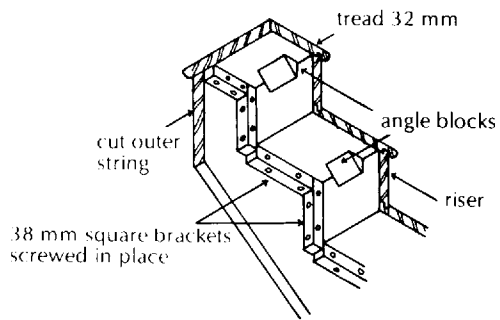
The nosing on treads usually projects 32 mm, or the thickness of the tread, from the face of the riser below. A greater projection than this would increase the likelihood of the nosing splitting away from the tread and a smaller projection would reduce the width of the tread. The nosing is rounded for appearance. Figure 162 illustrates the more usual finishes to nosings.

Strings (stringers) are cut from boards 38 or 44 mm thick and of sufficient width to contain and support the treads and risers of a flight of steps. Staircases are usually enclosed in a stair well. The stair well is formed by an external wall or walls and partitions, to which the flights and landings are fixed. The string of a flight of steps which is fixed against a wall or partition is the wall string and the other string the outer string, unless it is also fixed to a wall or partition when it is also a wall string (this will occur with a straight flight between walls).

A string which encloses the treads and risers it supports is termed a close or closed string. It is made wide enough to enclose the treads and risers and its top edge projects some 50 or 63 mm above the line of the nosings of treads. The width of the string above the line of nosings is described as the margin. Figure 163 shows a closed string. A string 250 or 280 mm wide is generally sufficient to contain steps with any one of the dimensions of rise and going and a 50 mm margin.

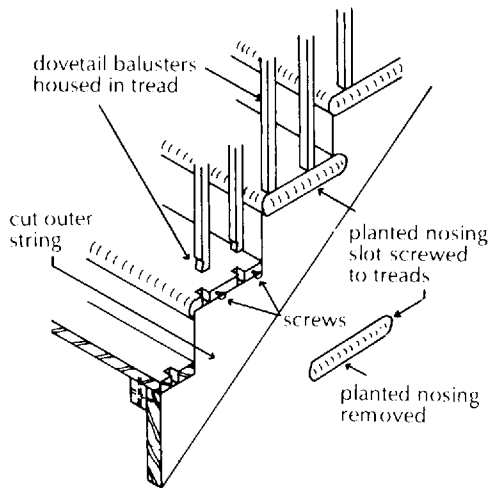
Wall strings are generally made as close strings so that wall plaster can be finished down on them. Outer strings can be made as closed strings or as open (cut) strings.

The ends of the treads and risers are glued and wedged into shallow grooves cut in closed string. The grooves are cut 12 mm deep into strings and tapering slightly in width to accommodate treads, risers and the wedges which are driven below them, as illustrated in Fig. 163.



**Fig. 164** Underside of flight to show fixing of treads, and risers to cut outer string.

## Cut or open string



**Fig. 165** Cut string.

After the treads and risers have been put together and glued and wedged into their housings in the string, angle blocks are glued in the internal angles between the underside of treads and risers and treads and risers and string. Angle glue blocks are triangular sections of softwood cut from say 50 mm square timber and each 120 mm long. Their purpose is to strengthen the right angled joints between treads, risers and strings. Three or four blocks are used at each junction of tread and riser and one at junctions of treads, risers and string. Angle blocks are shown in Fig. 164.

A closed outer string looks somewhat lumpy and does not show the profile of the treads and risers it encloses. The appearance of a staircase is considerably improved if the outer string is cut to the profile of the treads and risers. This type of string is termed a cut or open string. Because more labour is involved, a flight with a cut string is more expensive than one with closed strings.

As the string is cut to the outline of the treads and risers they cannot be supported in housings in the string and are secured to brackets screwed to both treads and risers and string, as illustrated in Fig. 164. It is difficult to cut a neat nosing on the end grain of treads to overhang the cut string, so planted nosings are fitted as shown in Fig. 165. The planted nosings are often secured to the ends of treads by slot screwing. This is a form of secret fixing used to avoid having the heads of screws exposed. Countersunk head wood screws are driven into the ends of treads so that their heads protrude some 12 mm. The heads of these screws fit into holes cut in the nosing. The nosing is then knocked into position so that the screw head bites into slots cut next to the holes in the nosing. It will be seen from Fig. 165 that the planted nosings are mitred to the nosing of the tread. The ends of the risers are cut at 45° to the face of the string. Because the string is thicker than the riser it partly butts and is partly mitred to it, as a mitre and butt joint.

## Landings

### Half space (turn) landing

A half space landing is constructed with a sawn softwood trimmer which supports sawn softwood landing joists or bearers and floor boards, as illustrated in Fig. 166. As well as giving support to the joists of the half turn landing the trimmer also supports a newel or newel posts. Newel posts serve to support handrails and provide a means of fixing the ends of outer strings.

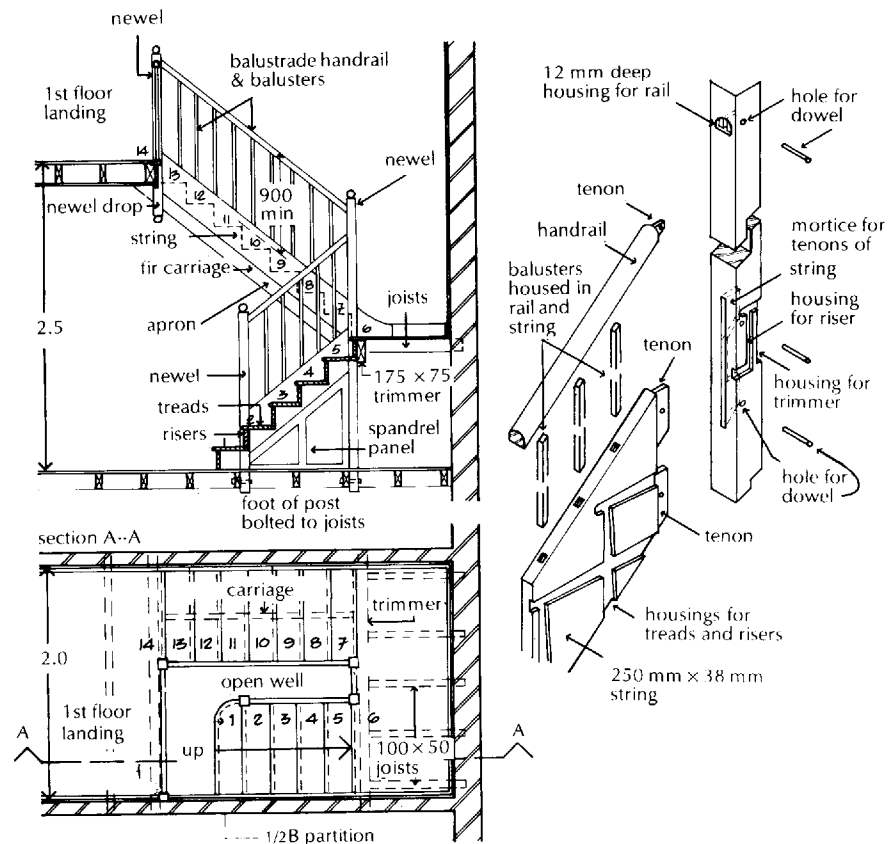


Fig. 166 Half turn open well staircase.

Plan

## Newel posts

The newel posts are cut from  $100 \times 100$  mm timbers and are notched and bolted to the trimmer. The outer string fits to mortices cut in the newel, as illustrated in Fig. 166. For appearance, the lower end of the newel post is usually about 100 mm below the flights and moulded. As it projects below the stair it is called a drop newel.

## Balustrade

### Open balustrade

The traditional balustrade consists of newel posts, handrail, and timber balusters, as illustrated in Fig. 166. The newel posts at half turn landings and at landings at first floor level are housed and bolted to trimmers. These newels are fixed in position so that the faces of the risers at the foot and head of flights are in line with the centre line of the newel.

## Handrail

The top of the handrail is usually fixed a minimum height of 900 mm vertically from the pitch line to the top of the handrail and 900 mm above landings for domestic stairs in a single house and 900 to 100 mm above the pitch line for other stairs. The handrail is cut from

75 × 50 mm timber which is shaped and moulded. The ends of the handrail are tenoned to mortices in the newels.

## Balusters

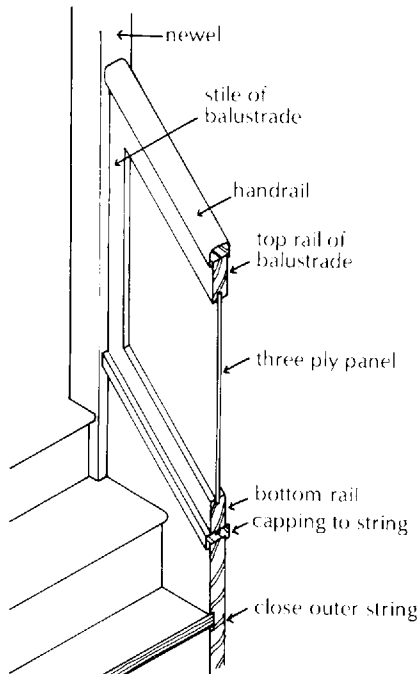


Fig. 167 Enclosed balustrade.

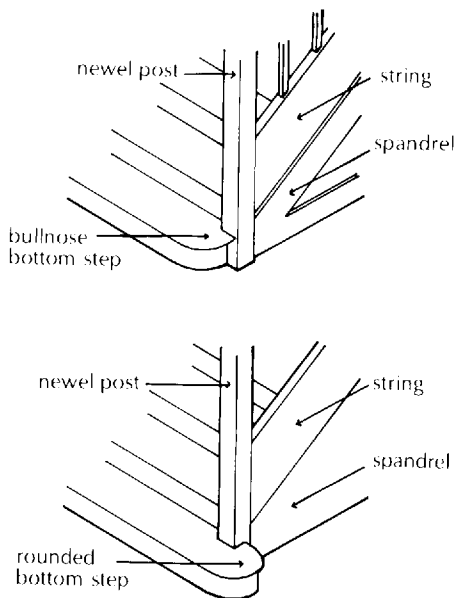


Fig. 168 Shaped steps.

Balusters may be 25 or 19 mm square or moulded. They are either tenoned or housed in the underside of the handrail and tenoned into the top of closed strings or set into housings in the treads of flights with cut string, as shown in Fig. 165.

To prevent children under 5 years of age from becoming stuck between them balusters should be so spaced that a 100 mm sphere cannot pass between them.

The traditional balustrade of vertical balusters, either plain or moulded, may not provide a satisfactory looking enclosure to stairs for some. A fashion for so called modern looking balustrades in the form of closed balustrades of panels of wood or plywood was taken up from time to time, in the first half of the twentieth century. The disadvantage of the enclosed panel balustrade is that it makes the stair somewhat dark.

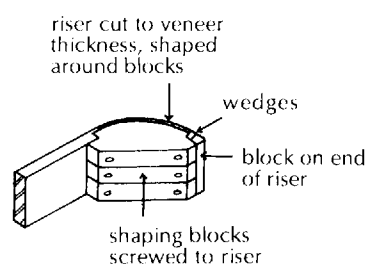
More recently the fashion has been for enclosed glass panelled balustrades with the glass set in a metal channel above the pitch line to concrete steps or stairs and set into a channel fixed under or below a handrail.

An enclosed balustrade to a close string stair is illustrated in Fig. 167, with a plywood panel set in a softwood frame fixed between the top of a close, outer string and the underside of the handrail.

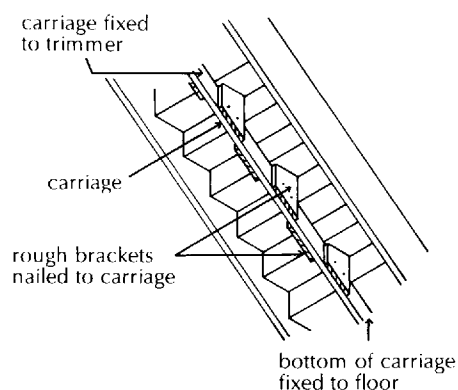
For the sake of appearance the bottom step of a timber staircase may be framed to project beyond the newel post and be shaped as either a quarter or a half circle as illustrated in Fig. 168. By projecting from the enclosing strings into the floor the bottom step gives the sense of the stair belonging to the floor as well as the staircase.

The bullnose, quarter circle and the rounded, half circle, end steps are made by cutting the riser to the thickness of a veneer of thin wood which is shaped around three shaping blocks to which the reduced thickness of the riser is screwed as illustrated in Fig. 169. A block left on the end of the riser is wedged to the blocks to shape the riser tightly around the blocks.

The tread is cut with a projecting nosing to return around the shaped bottom step.



**Fig. 169** Bullnose step.



**Fig. 170** Underside of flight showing carriage and brackets.

## Winders

The triangular space between the underside of the lower flight of a stair and the floor is the spandrel. It may be left open and be a nuisance to keep clean or more usually it is enclosed with spandrel filling of a sheet of plywood or other board or closed with timber framed panelling as illustrated in Fig. 168. Where the length of the spandrel filling is sufficient, the panelling may be framed around a door so that the spandrel space below the stair may be used for storage.

A sawn softwood carriage is usually fixed below flights of a staircase to give support under the centre of each step. The fir (softwood) carriage illustrated in Fig. 170 is  $100 \times 75$  mm in section and nailed to landing trimmers or joists for support with the top surface of the carriage directly under the angle of junction of treads and risers.

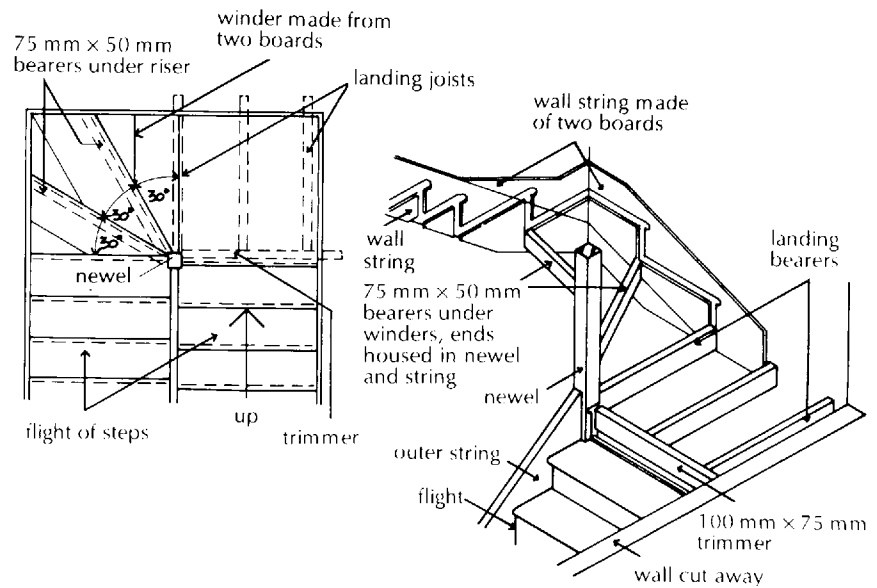
Short offcuts from  $175 \times 25$  mm boards are nailed alternate sides of the carriage, so that the top edge of these brackets bears under treads to reduce creaking of the stair.

Where the soffit of flights of staircases is to be plastered two additional fir carriages should be fixed, one next to the wall and the other next to the outer string as fixing for plasterboard.

Winders is the name given to tapered treads that wind round quarter or half turn stairs in place of landings to reduce the number of steps required in the rest of the stair and to economise in space. These winders may be used in domestic stairs. They present some hazard to the young and elderly and are not recommended for use in means of escape stairs or stairs in public buildings. The winders illustrated in Fig. 171 are constructed as three taper treads at the quarter turn of a half turn stair with a quarter turn landing leading down to the lower flight.

The newel post is continued down to and supported at the floor below so that it may support the trimmer for the quarter space landing and the bearers for the winders. The treads of the winders are made of two boards tongued and grooved together. To support the edge of winders  $75 \times 50$  mm bearers are housed in the newel post and wall string.

Because of the extra width of the tread of winders where they are housed in wall strings the wall string has to be made of two boards into which both treads and risers are housed in 12 mm grooves and wedged and glued.



**Fig. 171** Winders and quarter space landing.

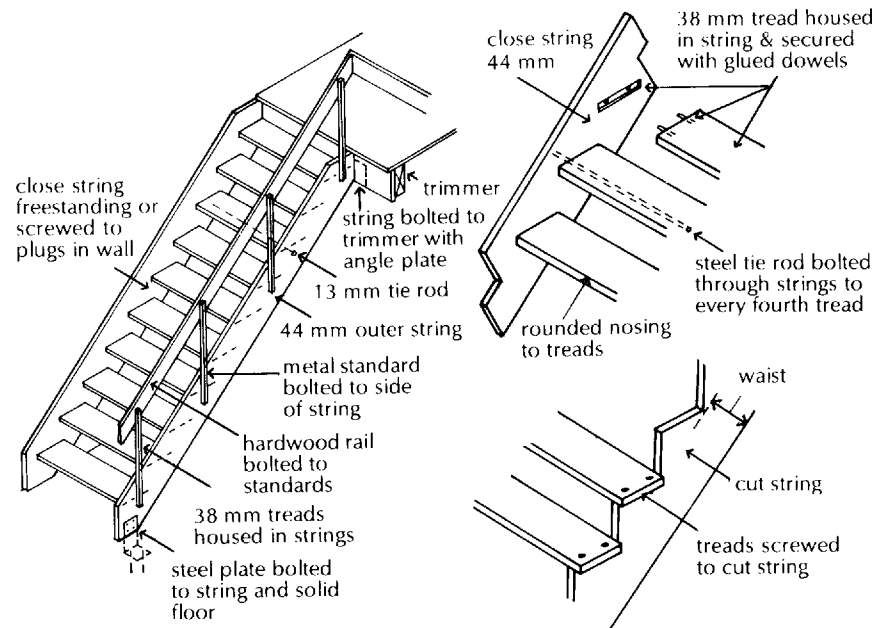
## OPEN RISER OR LADDER STAIR

An open riser or ladder stair consists of strings with treads and no risers so that there is a space between the treads, with treads overlapping each other at least 16 mm.

Open riser stairs have become fashionable particularly in open plan houses and flats with the open riser stair used as a feature. Various materials and forms of construction are used for exposed open riser stairs such as wood strings, treads and handrail, reinforced concrete strings and treads, reinforced concrete central carriage with cantilever treads, steel strings and treads to steel handrail supporting glass treads hung from the handrails.

More traditional open riser stairs are illustrated in Fig. 172. The strings may be either close or cut to the outline of the treads. The treads, which gain no support from risers, should be cut from 38 or 44 mm thick timbers which are housed in closed strings, as illustrated in Fig. 172, and secured in position with glued wood dowels.

To strengthen the fixing of the treads to the strings against shrinkage and twisting, 10 or 13 mm tie rods, one to every fourth tread, are bolted under the treads through the strings, as illustrated in Fig. 172. The strings are fixed to the floor with steel plates which are bolted to the sides of the timber strings and bolted to timber trimmers or cast into concrete floors (Fig. 172). The treads are screwed to the cut top edge of the strings and this fixing is sufficient to tie the strings together without the use of the rods. A cut string will generally need to be deeper than a similar close string because the effective depth of the cut string is the narrow waist below the junction of the back of a tread and the underside of the string.



**Fig. 172** Open riser stair with closed or cut string.

## Open riser wood stair

Open riser wood stairs are often constructed as straight flight stairs between floors and there is no newel post to provide a fixing for the handrail. The handrail and balustrade are fixed to the sides of the strings, as illustrated in Fig. 172.

## STONE STAIRS

The traditional stone stairs were constructed of steps of natural stone of rectangular or triangular section built into an enclosing wall so that each stone was bedded on the stone below in the form of a stair. Each stone was built into the wall of the stair well from which it cantilevered and took some bearing on the stone below in the form of a prop cantilever. The steps were either of uniform rectangular section with a stepped soffit or rectangular section cut to triangular section to form a flush soffit, as illustrated in Fig. 173. The ends of the crude rectangular section steps were built into a wall. The ends of the triangular section steps had their rectangular ends built in. These steps had splayed rebated joints and nosings cut on the edge of the tread surface, as illustrated in Fig. 173. Landings were constructed with one or more large slabs of natural stone built into enclosing walls and bearing on the step below.

Because of the scarcity and cost of natural stone, this type of step is now made of cast stone or cast concrete which is usually reinforced and cast in the same sections as those illustrated for natural stone, or as a combined tread and riser with a rectangular end for building into walls and a stepped soffit.

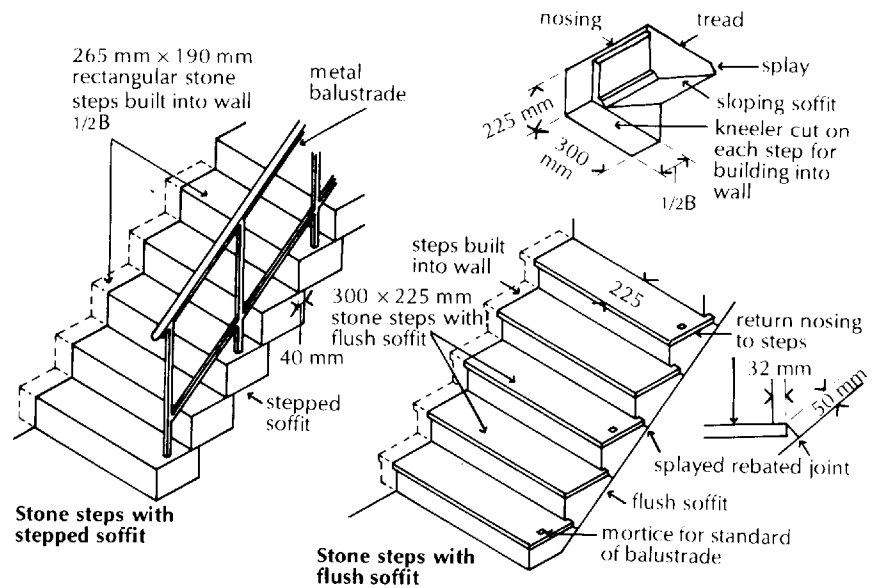


Fig. 173 Stone steps.

## REINFORCED CONCRETE STAIRS

With the use of the reinforced concrete skeleton frame (see Volume 4), as one of the principal structural frames for the majority of buildings of more than three or four floors, a reinforced concrete stair, either cast in situ, precast or a combination of in situ and precast, is the usual form of stair today.

### Fire safety

A reinforced concrete stair, which has better resistance to damage by fire than the conventional timber staircase, is used for access and means of escape stairs in most buildings of more than three or four storeys. The width, rise, going and headroom for these stairs and the arrangement of the flights of steps as straight flight, quarter turn, half turn and geometrical stairs is the same as for timber stairs.

The usual form of a reinforced concrete stair is as a half turn (dog leg) stair either with or without an open well. The construction of the stair depends on the structural form of the building and the convenience in casting the stair in situ or the use of reinforced concrete supports and precast steps.

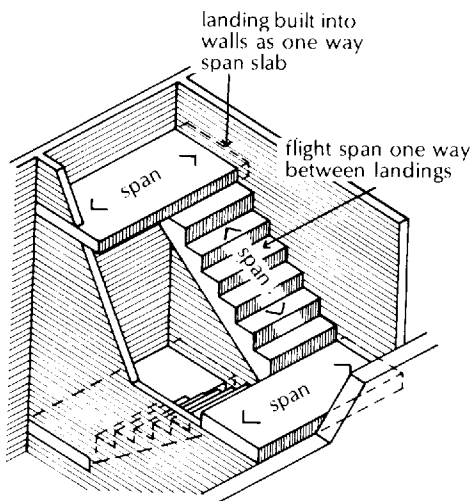
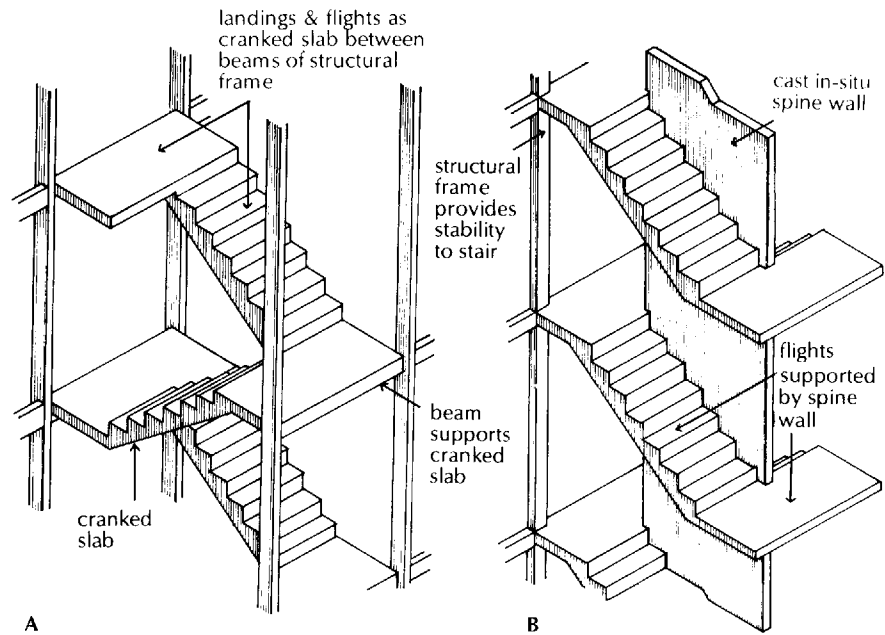


Fig. 174 Inclined slab stair.

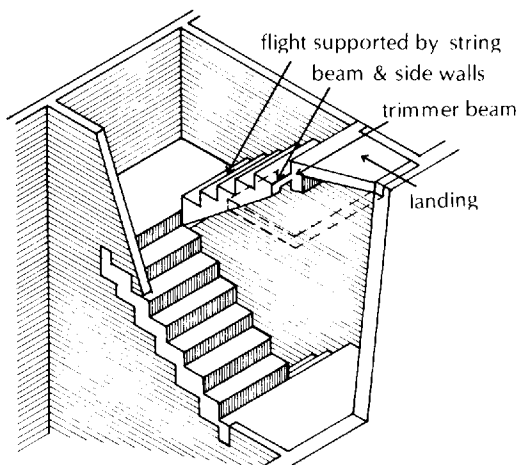
Where there are load bearing walls around the stair it is generally economic to build the landings into the side walls as one-way spanning slabs and construct the flights as inclined slabs between the landings as illustrated in Fig. 174. This form of stair is of advantage where the enclosing walls are of brick or block as it would involve a great deal of wasteful cutting of bricks or blocks were the flights to be built into the walls and the bricks or blocks cut to fit to the steps.



As an alternative the stair may be designed and constructed as a cranked (bent) slab spanning through landing, flight and landing as one slab with no side support as shown in Fig. 175A. This is a more costly construction than using the landings as slabs to support the flights as the span and therefore the cost of the stair is greater. This form of construction is used where the landings cannot gain support each side of the stair.



**Fig. 175** A Cranked slab stair.  
B Cantilevered spine wall stair.



**Fig. 176** String and trimmer stair.

Another construction is to form a reinforced concrete frame of beams to landings supporting inclined beams to flights, as illustrated in Fig. 176. The landing beams are supported by side walls or the beams of a frame and in turn support inclined beams that support the steps. This is a somewhat clumsy form of construction with a very untidy soffit or underside to the stair. It is best suited to the use of precast concrete steps that bear on the inclined beam under the flight with step ends built into enclosing walls or on two inclined beams and the use of precast landings.

Where a reinforced concrete half turn stair is constructed around a reinforced concrete centre spine wall between the flights, the stair may be constructed to cantilever from this spine wall, as illustrated in Fig. 175B, or partly cantilever from the spine wall and be supported by the enclosing frame or walls.

The reinforcement of a concrete stair depends on the system of construction adopted. The stair illustrated in Fig. 177 is designed and built with the landings built into the enclosing walls as a two-way

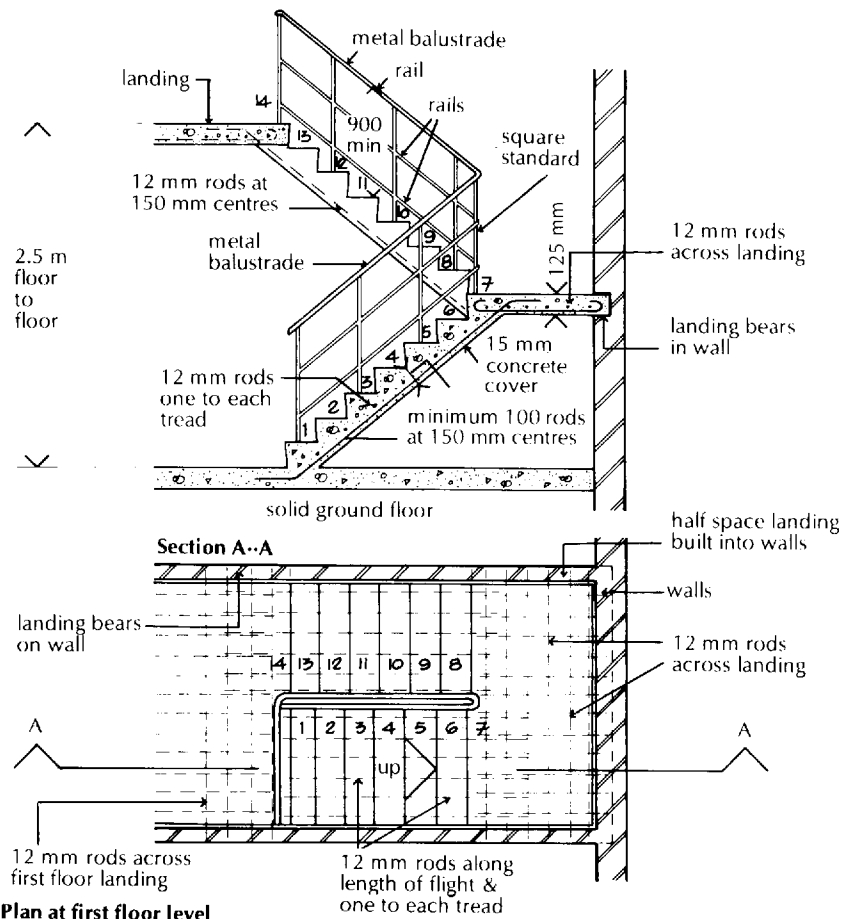


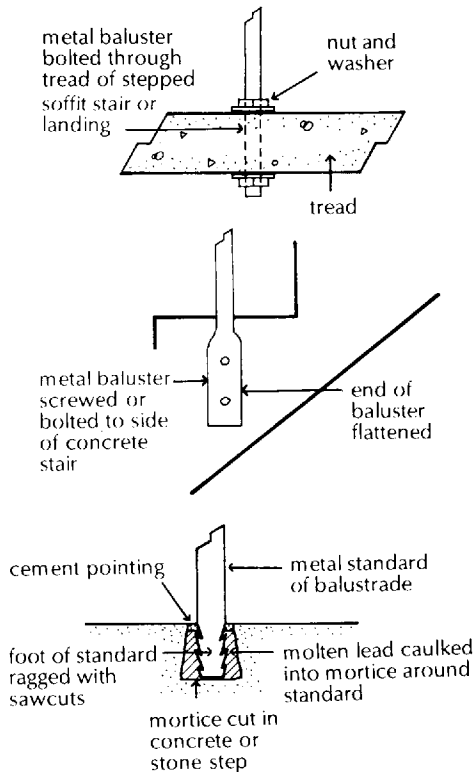
Fig. 177 Half turn reinforced concrete stair.

Plan at first floor level

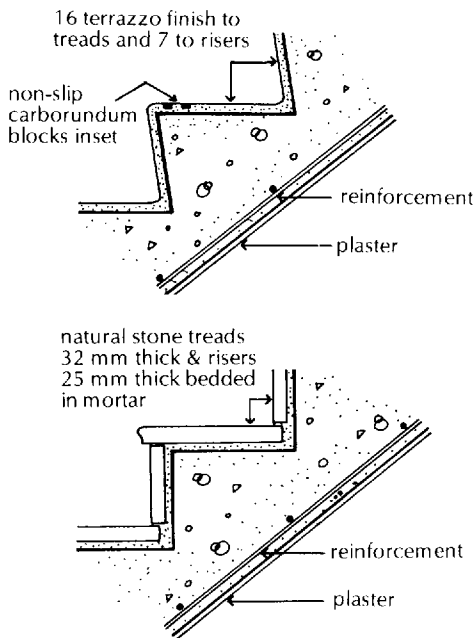
slab, and an inclined slab as flights spanning between landings independent of the side walls. The main reinforcement of the landings is both ways across the bottom of the slab, and the main reinforcement of the flights is one way down the flights. The effective depth of the inclined slab that forms the flights is at the narrow waist formed on section by the junction of tread and riser and the soffit of the flight. It is this thickness of the slab that has constructional strength and the steps play no part in supporting loads. The reinforcement has to have cover of concrete around it to inhibit rust and protect steel rods against damage by fire.

## Balustrade

The balustrade to a stone, cast stone or reinforced concrete stair is usually of metal, the uprights of which are either bolted to the sides of the flights to studs cast or grouted into the material or bolted through the material or set in mortices either cast or cut in the material. These vertical metal supports or standards in turn support rails as a balustrade for security and a handrail.



**Fig. 178** Setting metal standard in stone or concrete step.



**Fig. 179** Finishes to concrete steps.

To provide maximum rigidity for the uprights which support a balustrade and handrail for stone or concrete stairs and landings, the uprights should be bolted through the thickness of the flights and landings as illustrated in Fig. 178. The metal uprights are bolted with nuts and washers through the depth of the stair. Uprights at some 900 to 1200 mm intervals will support a frame fixed just above pitch line and up to and including a handrail.

As an alternative fixing, for flush sloping soffit flights for example, the uprights may be secured by expanding bolts to the side of a reinforced concrete stair as illustrated in Fig. 178.

The traditional method of fixing the metal uprights, standards or balusters to natural stone stairs and landings is by fixing the end of the verticals into a mortice cut in the stone. The ragged end of the verticals is then set in the mortice and molten lead is run into the mortice and caulked (rammed) to complete the joint as illustrated in Fig. 178.

As this fixing for the uprights of a balustrade is not so rigid or secure as bolting through, the uprights have to be at fairly close intervals of 400 to 600 mm to support the balustrade frame and handrails.

Hard, durable, natural stone steps and landings may be left as a natural finish for the benefit of the appearance of the stone. Even the hardest natural stone will become scuffed and dirty in time and is laborious to keep clean.

Usually stone and concrete stairs are given an applied finish to create a surface which is easy to clean and for appearance. Any one of the floor finishes used for solid floors, as described in Volume 1, may be used for stairs. In situ or precast terrazzo is often used for its appearance and ease of cleaning, with carborundum inserts as a non-slip surface, as illustrated in Fig. 179. Wood treads of hardwood screwed to plugs in each step provide an attractive, durable and quiet-in-use surface. Stone treads and risers may be bedded as a surface finish for reinforced concrete stairs, as illustrated in Fig. 179.

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## 4: Fires, Stoves and Chimneys

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### HISTORY

For centuries the fuel used for heating and cooking was wood. Prior to the Industrial Revolution the ready availability of this free source of fuel was adequate to the modest needs of the comparatively small population of England.

In the early years of the Industrial Revolution the development of deep coal mining provided a source of fuel for heating and cooking for the increasing population of urban dwellers as a substitute for the depleted sources of wood.

The disadvantage of the solid fuels wood and coal as a fuel is that they are laborious to deliver, bulky to store and dirty in use and produce ash which is tedious and messy to dispose of.

The advantage of coal is that it is plentiful, provides a cheerful flame or glow when it burns and provides a traditional focal point in a room. Smokeless fuels and coke, derivatives of coal, are lighter, cleaner and produce less ash than household coal but nonetheless require space for storage and effort in use, unlike the convenience fuels gas, oil and electricity.

During the last 50 years there has been a move away from the use of solid fuel burning fires and stoves for heating to the use of gas, oil and electricity for heating for the convenience in using these sources of energy for heating and because of legislation to create smokeless zones to control fog.

The most convenient method of heating is by electricity which can be controlled by the touch of a switch, requires only slender cables to distribute energy and needs very little attention from the consumer. It is extravagant to convert natural fuels such as coal, gas and oil to electricity which is the most costly source of energy for heating. Oil, which is a comparatively cheap source of energy for heating and requires bulky storage containers, has by and large been replaced by natural gas as the principal source of energy for heating.

### Solid fuels

The solid fuels available are bituminous coal (house coal), anthracite, smokeless fuels, coke, wood and peat.

### Coal

Bituminous coal or house coal is a natural coal that ignites easily and burns with a bright flame. It is the traditional solid fuel for the open fire, much enjoyed for its bright flame and cheerful glow and equally hated for the need for frequent fuelling, cleaning of ash and the smoke pollution in towns that was a prime cause of fog. In smoke control

areas, only authorised fuels may be used and house coal is generally prohibited.

## **Anthracite**

Anthracite is a dense natural fuel that burns slowly and is a natural smokeless fuel. The limited supplies of this fuel are used in stoves and boilers.

## **Smokeless fuels**

Smokeless fuels are produced by processing coal to produce a smokeless fuel, for use in smoke control areas. Smokeless fuel is less dense and cleaner to handle than natural coal, burns with a glow rather than a flame and produces a fine ash.

Coke is the by-product of the conversion of coal to town gas (see Volume 5). It is light in weight, clean to handle, burns with a glow and is smokeless, but produces hard clinker and ash which is messy to dispose of.

## **Wood**

There are limited supplies of wood for use as fuel for heating in this country. The large volume of wood required for heating necessitates large open fires or stoves and considerable storage space.

## **Peat**

Peat, which is compressed, decayed vegetation, is cut and used as a fuel mainly in Ireland and the west of England.

## **FUNCTIONAL REQUIREMENTS**

The functional requirements of fires and chimneys are:

- Strength and stability
- Resistance to weather
- Fire safety
- Resistance to the passage of heat
- Ventilation

## **Strength and stability**

Conventional flues to open fires and stoves are constructed as chimneys built into chimney breasts as part of a wall or internal division. In effect the chimney is part of the wall or internal division into which it is built and should be constructed to meet the requirements for strength and stability that apply to the wall. Freestanding chimneys of brick or block are similar to freestanding piers and should meet the requirements for strength and stability that apply to piers.

## **Resistance to weather**

Brick and block chimneys that are formed as part of an external wall and are carried up above roofs to discharge the products of combustion should be constructed to meet the requirements to resist the penetration of rainwater to the inside of the building in the same way that external walls and parapets do.

## Fire safety

The requirements for fire safety are set out in Approved Document J, Heat Producing Appliances, to the Building Regulations. The requirements set minimum thickness and dimensions of non-combustible materials around fires, flues and hearths and minimum dimensions for the proximity of combustible materials to fires and flues.

## Resistance to the passage of heat

Open fires inset in an opening in a chimney breast constructed as part of an external wall transmit a large part of the heat produced by burning fuel to the surrounding wall which will conduct heat to the outside. To minimise this wasteful loss of heat, the wall behind a fireplace should be constructed as an insulated cavity wall to gain the maximum benefit of the radiation of heat from the wall into the building.

## Ventilation

For combustion, fuel requires a continuous intake of air both for the process of burning and to carry the products of combustion to outside air. Solid fuels, such as wood and coal, burning vigorously in open fires draw in considerable volumes of air. The necessary air intake is advantageous in providing beneficial air changes and disadvantageous in the inevitable draughts of cold air intake from windows and doors that are a feature of open fires.

## SOLID FUEL BURNING APPLIANCES

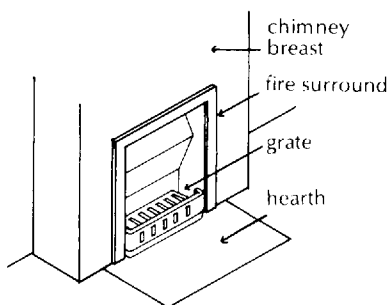
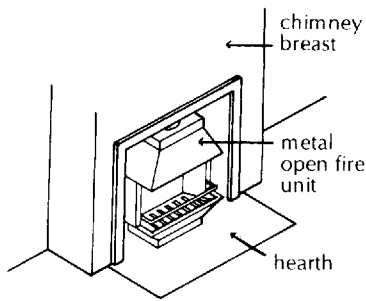


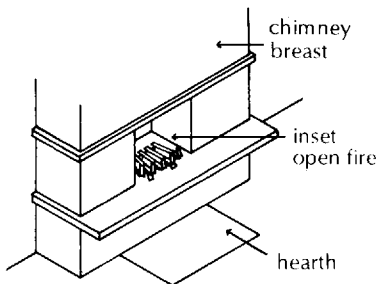
Fig. 180 Open fire inset in recess.

Solid fuels are burned in open fires, room heaters or stoves and boilers for heating and hot water.

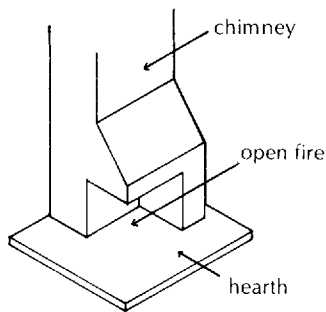
The traditional open fire consists of a grate inset in a fireplace recess formed in a brick chimney breast, as illustrated in Fig. 180. As its name implies, an open fire is clearly visible and this is its chief attraction. The disadvantage of an open fire is that much of the air drawn into the fire and up the chimney by convection is not necessary for combustion or burning the fuel and this excess air wastefully takes a large proportion of the heat from the fire up the chimney. The air drawn into the fire is replaced by air drawn into the room which causes draughts of cool air which are uncomfortable and wasteful of heat. An open fire inset in a recess in a chimney built into an external wall will heat the brickwork or blockwork in which it is contained. Some of the heat will be lost to outside air by conduction.



**Fig. 181** Freestanding open fire in recess in chimney breast.



**Fig. 182** Open fire inset above floor level in brick or block chimney breast.



**Fig. 183** Freestanding open fire with brick or block chimney.

The freestanding open fire illustrated in Fig. 181 has some advantage in that the fire is contained inside the freestanding metal surround and hood, which will radiate heat into the room and around which air will circulate to transfer heat by convection. Plainly the degree to which these effects will occur will depend on the extent to which the fire is set outside the recess in the chimney. To limit the volume of air drawn into the fire, to that necessary for burning, the hood of these fires is connected by a short length of stove pipe that connects to the flue through a hole in a plate fixed across the bottom of the flue.

The conventional open fire is formed at floor level on a solid hearth as part of a concrete floor or constructed in a timber floor for the sake of convenience in construction. In this position the fire will radiate much of its heat at floor level. So that an open fire will radiate heat more uniformly into the body of a room the fire may be raised above floor level as illustrated in Fig. 182. A raised hearth of stone or concrete is built into the chimney breast to project from the face of the chimney to collect so much of the burning fuel as might otherwise fall on to the floor. As a safeguard a hearth is formed at floor level in timber floors to collect any burning material that falls from the upper hearth. As an alternative a grate may be set in a perforation in the upper hearth so that burning material and ash fall into a metal ash can set below the upper hearth.

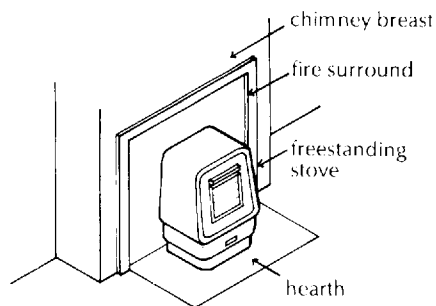
An advantage of this arrangement is that the comparatively small opening of conventional open fires is more visible.

The most convenient place for an open fire in the comparatively small rooms of most houses is centrally in one long wall. In larger living areas the fire may be built as a freestanding structure or fitting where it is visible from one or more sides and where the heat generated by the fire will radiate from all four sides more generally to the living space.

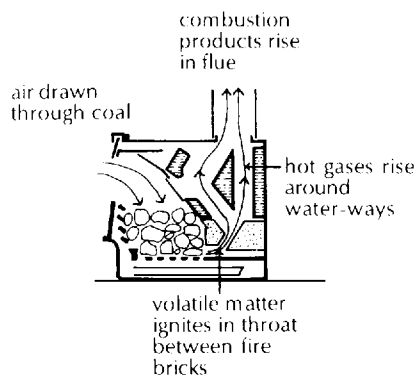
A freestanding open fire may be constructed as a brick or block chimney rising above the open hearth as illustrated in Fig. 183, where the fire is open and visible on two sides, or open on all four sides. The chimney is a form of freestanding pier, the dimensions of which are determined by the required cross-sectioned area to support the load of the chimney and slenderness ratio to resist overturning.

As an alternative a freestanding open fire may be formed as a hearth over which a metal hood and flue pipe are either supported from the floor or suspended from a ceiling.

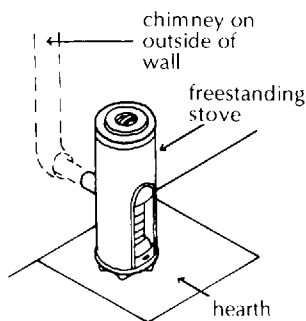
Room heater is a term recently used to describe an enclosed adaptation of the open fire designed for the more efficient use of solid fuel. It is a modern version of the traditional stove. The advantages of the



**Fig. 184** Freestanding stove (room heater).



**Fig. 185** Down draught solid fuel burning heater.



**Fig. 186** Freestanding stove connected to chimney.

room heater are that air intake and combustion can be controlled to appreciably reduce the intake of excess air and so reduce the wasteful flow of heated air passing up the chimney, and the whole of the surface area of a freestanding room heater is used to heat the room by radiation and convection of air around the heater. The room heater is set on a hearth in front of the chimney breast with a short length of flue pipe run from the back of the heater through a hole in the plate that seals the fireplace recess, as illustrated in Fig. 184. These heaters may be set inside a fireplace recess or set as freestanding heaters inside the room, depending on the room available in front of the heater and appearance.

A hinged fuel door or panel in the front of the heater is glazed to give a view of the fire.

The most efficient form of room heater is designed so that the primary combustion air intake is drawn down, through the bed of coal in the grate, and then up to the flue as illustrated in Fig. 185. For maximum efficiency a down draught room heater is combined with a back boiler to take advantage of the heated combustion gases passing from the fire up the chimney. These back boilers are used to heat water and radiators.

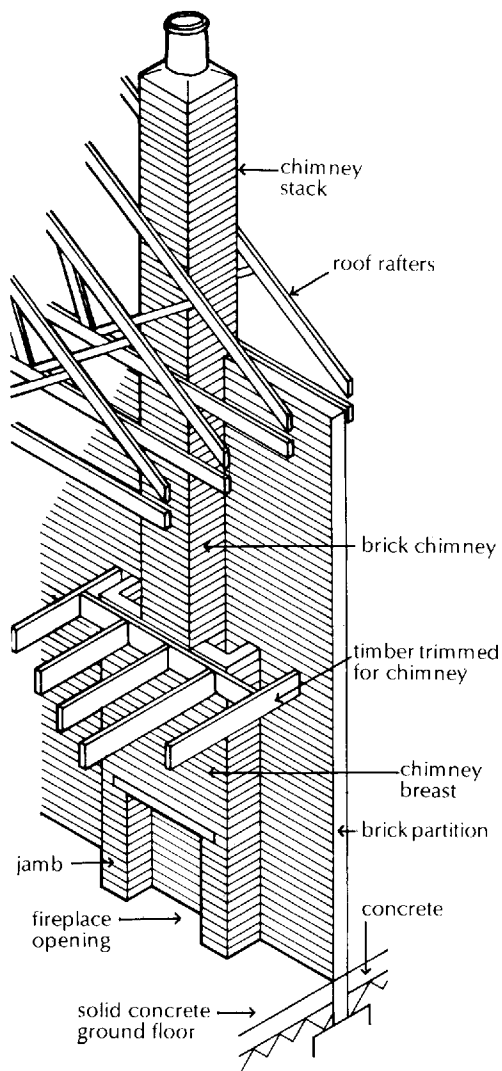
The cast iron back boiler is formed with flue ways running between the hollow cast iron waterways to provide maximum area of waterways exposed to hot combustion gases rising up to the flue. Fire bricks behind the grate and below the back boiler are chosen to take up and retain heat to ignite volatile gases flowing up through the back boiler flue ways. A steel plate damper which is adjustable to control air intake is opened when the fire is first lit and later when refuelled to promote a vigorous draught of air up the flue and subsequently closed to reduce air intake to promote steady, efficient ignition of fuel. The traditional room heater used in most parts of central Europe is a stove in the form of an enclosed solid fuel burning appliance of cast iron, steel or brick. The smaller iron or steel stoves are used to burn wood or coal or both to heat small rooms and the large brick stoves burn wood to heat larger rooms.

The traditional stove is set freestanding in rooms adjacent to a wall into which, or against which, a metal flue pipe is run to open air. Like room heaters the advantages of a stove are that air intake can be controlled for maximum efficiency and the whole of the heated outer surface of the stove is exposed for maximum radiation and convection of heat to rooms. Figure 186 is an illustration of a freestanding iron stove suited to heating small rooms and fuelled by wood or coal or both which are fed to the stove through a loose top cover plate.



A boiler is an enclosed appliance in which fuel is burned specifically to heat water for a hot water supply or for space heating or both. The fuel burned in a hearth heats water run inside cast iron sections around the hearth, the heated water flowing either by gravity or pump to hot water cylinders and radiators and back to the boiler for reheating.

## CHIMNEYS AND FLUES



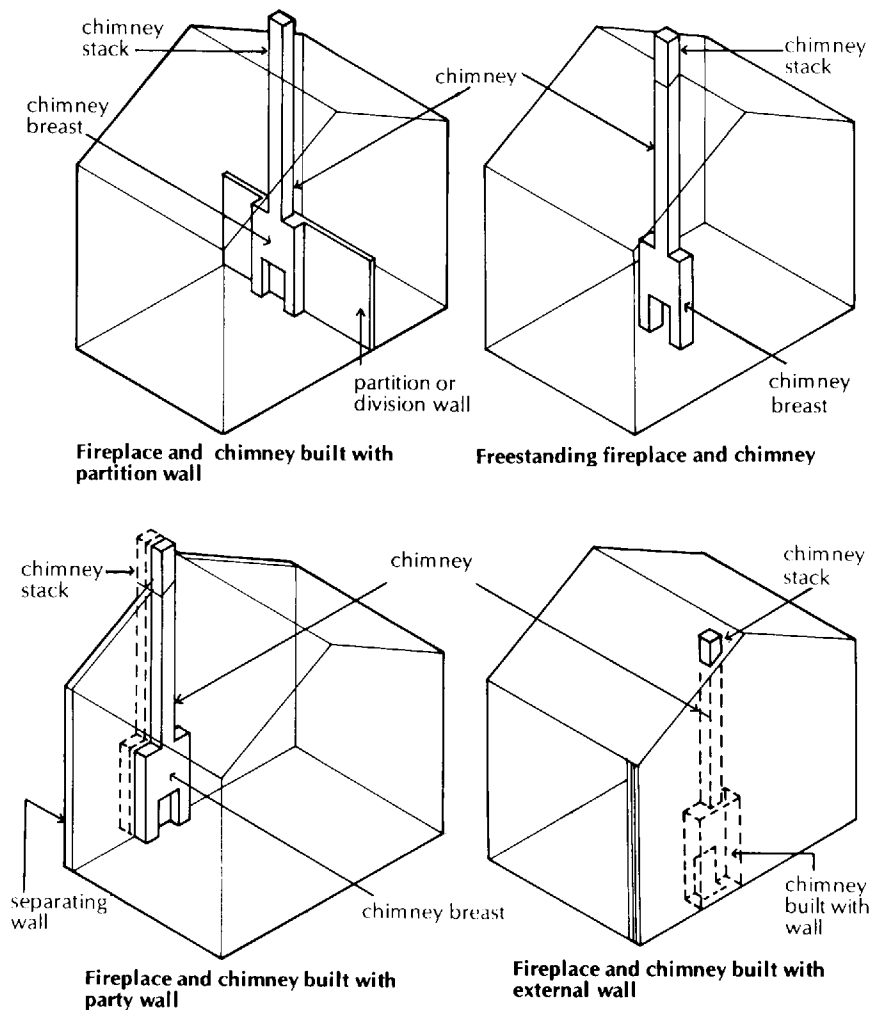
**Fig. 187** Brick chimney and chimney breast.

A flue is a shaft, usually vertical, to induce an adequate flow of combustion air to a fire and to remove the products of combustion to the outside air. The material which encloses the flue, brick, block, stone or metal, is termed a chimney. A chimney may take the form of a pipe run to the outside or be constructed of solid brick, block or stone either freestanding or as part of the construction of a partition or wall. The conventional chimney for open fires and stoves is constructed of block, brick or stone and consists of a fireplace recess contained between jambs over which a chimney breast gathers into a chimney that is carried above roof level as a chimney stack (Fig. 187). Because a fireplace and the enclosing jambs are wider than the chimney and flue above, the chimney breast is constructed to accommodate the gathering in of the fireplace opening to the smaller flue.

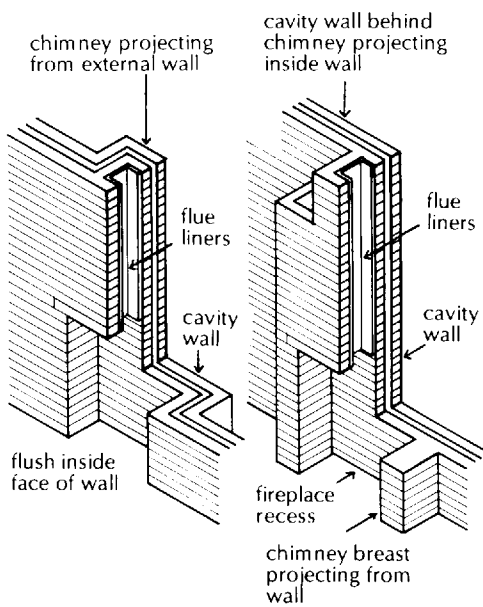
Some of the heat of combustion of fires and stoves will be transferred to the chimney, which heats the structure and air surrounding it. To take the maximum advantage of this heat the best position for a chimney is as a freestanding structure in the centre of a room or building where it is surrounded by inside air. As an alternative the chimney may be built as part of an internal partition. Where buildings are constructed with a common separating or party wall it is convenient to construct chimneys back to back on each side of the separating wall. Chimneys constructed as part of an external wall suffer the disadvantage that some of the heat will be transferred to the cold outside air. This loss can be minimised by continuing the cavity of an external wall and cavity insulation behind the chimney. The four positions for a chimney are illustrated in Fig. 188.

It is usual to construct chimney breasts and chimneys as projections into rooms heated by open fires as illustrated in Fig. 188, with the chimney breast projecting into the ground floor room and the chimney projecting into the room above. The advantages of this arrangement are that the heated surfaces of the breast and chimney will transfer some heat to inside by radiation and convection and that the projecting breast will give some emphasis to the comparatively small fireplace openings.

As an alternative the chimney breast and chimney may be constructed to project from the face of the internal or external wall



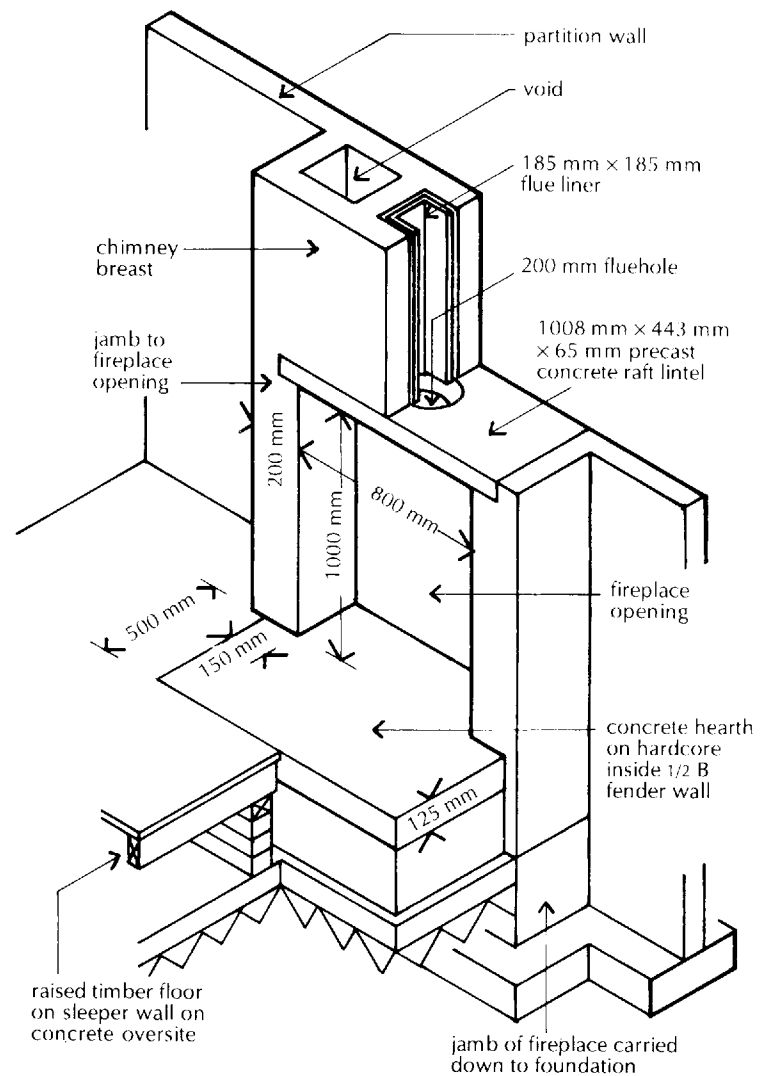
**Fig. 188** The four positions of fireplace and chimney.



**Fig. 189** Fireplace and chimney in cavity wall.

opposite to that of the fireplace recess, as illustrated in Fig. 189. Whether the chimney and breast projection is inside or outside of an external wall it is necessary to continue the cavity and any necessary cavity insulation behind fireplace openings and flues to exclude rain penetration and provide adequate resistance to heat transfer as illustrated in Fig. 189.

A fireplace or appliance recess is formed in the projecting chimney breast or wall into which the open fire or stove is set and above which the flue rises in the chimney breast. To support the brick or block work of the chimney breast over the fireplace opening, two piers are built either side of the recess. These piers, which are described as jambs (legs), support a brick arch or reinforced concrete lintel which supports the chimney breast. It is common to use a reinforced concrete raft lintel over the fireplace recess to support the chimney breast. The lintel is holed for the flue as illustrated in Fig. 190.



**Fig. 190** Fireplace, hearth and chimney.

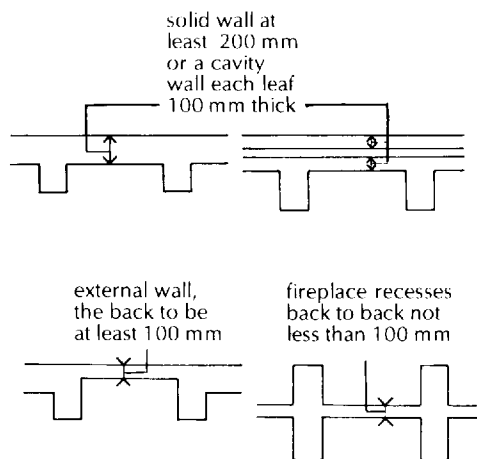
The traditional fireplace recess was usually about 580 mm wide and 625 mm high to accommodate a small domestic open fire. A larger opening 800 mm wide and 1000 mm high is often used to provide for wider open fires or for fitting in room heaters as illustrated in Fig. 190.

## FIRE SAFETY

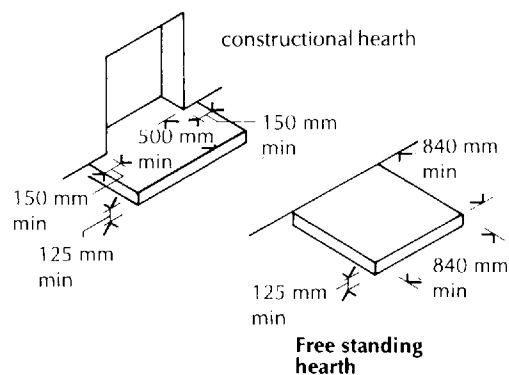
A requirement of the Building Regulations is that heat producing appliances be so installed and fireplaces and chimneys so constructed as to reduce to a reasonable level the risk of the building catching fire in consequence of their use.

### Fireplace recesses

The practical guidance given in Approved Document J, Heat Producing Appliances, to the Building Regulations, gives recommendations for the position and thickness of solid, non-combustible materials to be used in surrounds to open fireplaces and the thickness



**Fig. 191** Thickness at back of fireplace recess.



**Fig. 192** Constructional hearths.

and dimensions of solid, non-combustible materials in hearths under open fireplaces in, and in front of, open fireplace recesses.

The solid, non-combustible materials to enclose an open fire recess are brick, concrete block or concrete. The least thickness of these materials at the back of a fire place recess should be at least 200 mm of solid walling or each leaf of a cavity wall at least 100 mm and where fireplaces are built back to back at least 100 mm. As illustrated in Fig. 191. In an external wall with no combustible cladding there should be at least 100 mm of solid backing.

The least width of the jambs, 200 mm, at the sides of a fireplace opening is indicated in Fig. 190. This dimension applies whether the jambs project from a wall to support a projecting chimney breast or are part of the wall into which the recess is formed with the chimney breast or chimney projecting from the opposite side of the wall.

There should be an area of solid, non-combustible material in and projecting from fireplace recesses and under stoves, room heaters and other heat producing appliances. Where the floor under the fireplace recess and under heat producing appliances is at least 125 mm thickness of solid concrete the floor may be accepted as a hearth.

The minimum area and thickness of solid, non-combustible hearths in and in front of fireplaces and freestanding hearths are illustrated in Figs. 190 and 192.

Combustible material should not be under a hearth unless it is to support the edges of a hearth or there is an air space of at least 50 mm between the material and the underside of the hearth or there is a distance of at least 250 mm between the material and the top of the hearth.

A freestanding hearth should extend at least 840 mm around the back and sides of an enclosed heat producing appliance.

A heat producing appliance should be separated from combustible materials by some solid non-combustible material 200 mm thick if the appliance is 50 mm or less from the non-combustible material, and 75 mm thick if it is between 50 and 150 mm from the non-combustible material. The non-combustible material should extend at least 300 mm above the top of the appliance.

## FLUES

A flue is a shaft or pipe above a fireplace to induce combustion air to flow and carry away the products of combustion. Approved Document J gives practical guidance to meeting the requirements of Part J of Schedule 1 to the Building Regulations for an adequate supply of air to fixed heat producing appliances for combustion and the efficient working of flue-pipes or chimneys.

Section 2 of the guidance, which applies to solid fuel burning

appliances with a rated output up to 45 kW, requires a ventilation opening direct to external air of at least 50% of the appliance throat opening area, for open appliances, and at least 550 mm for each kW of rated output.

The requirements for an air supply for combustion, like the requirements for room ventilation, are dictated by the trend over recent years to air sealed windows and doors to contain heat and avoid draughts. The requirement for an adequate air supply for combustion must of necessity suppose a draught of cold outside air entering a room in which an open fire is burning vigorously, unless the fire or appliance is fitted with a separate air intake.

The practical guidance in Approved Document J to the Building Regulations sets out the minimum flue size shown in Table 8.

**Table 8** Size of flues.

| <b>Installation</b>                                         | <b>Minimum flue size</b>                     |
|-------------------------------------------------------------|----------------------------------------------|
| Fireplace recess up to 500 mm × 550 mm                      | 200 mm diameter or square of equivalent area |
| Inglenook recess appliances                                 | Free area 15% of area of the recess opening  |
| Open fire                                                   | 200 mm diameter or square of equivalent area |
| Closed appliance up to 20 kW output burning bituminous coal | 150 mm diameter or square of equivalent area |
| Closed appliance up to 20 kW output                         | 125 mm diameter or square of equivalent area |
| Closed appliance above 20 kW and up to 30 kW output         | 150 mm diameter or square of equivalent area |
| Closed appliance above 30 kW and up to 45 kW output         | 175 mm diameter or square of equivalent area |

Taken from Approved Document J, The Building Regulations 1991, HMSO.

For maximum efficiency the flue should be straight and vertical without offsets. As the heated products of combustion pass up the flue they cool and tend to condense on the surface of the flue in the form of small droplets. This condensate will combine with brick, block or stone work surrounding the flue to form water-soluble crystals which expand as they absorb water and may cause damage to the chimney and finishes such as plaster and paint. To protect the chimney from possible damage from the condensate, to encourage a

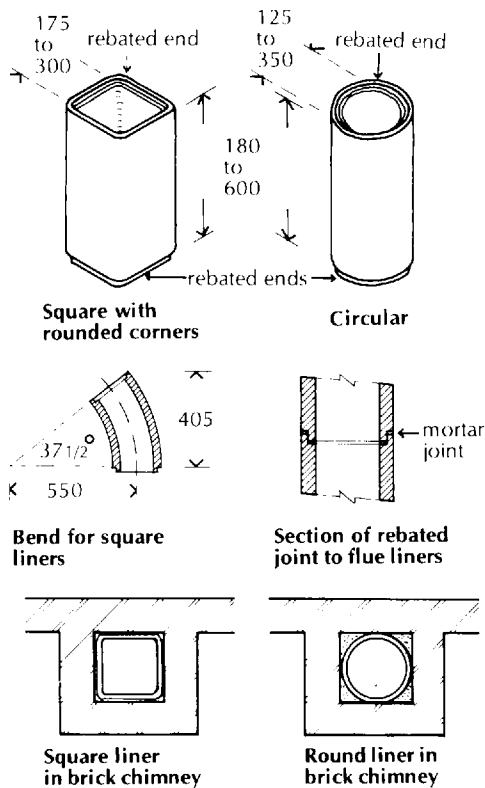


Fig. 193 Clay flue liners.

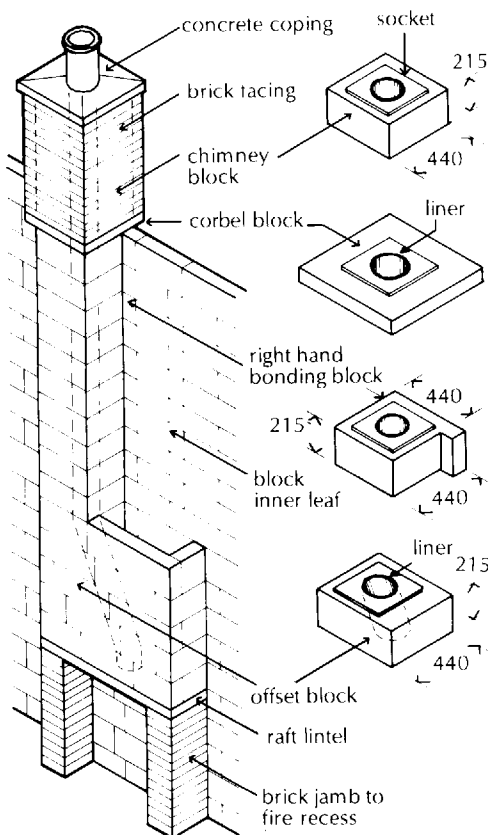


Fig. 194 Precast concrete block chimney.

free flow of air up the flue and to facilitate cleaning the flue, flue liners are built into flues.

Flue liners are made of burnt clay or concrete. Clay flue liners are round or square with rounded corners in section and have rebated ends (Fig. 193). These liners are built in as the chimney is raised and supported on raft lintels over fireplace openings, and the liners are surrounded with mortar and set in place with the liner socket uppermost so that condensate cannot run down through the joint into the surrounding chimney. Bends are made of the same cross sections for use where flues offset.

Concrete flue liners are made of high alumina cement and an aggregate of fired diatomaceous brick or pumice cast in round sections with rebated ends.

Clay drain pipes with socket and spigot ends may be used instead of flue liners. The pipes are set in place as the chimney is raised with the spigot ends of the pipes uppermost. Because of the appreciable projection of the socket ends of these drain pipes a chimney built with them is larger than one with purpose-made flue liners.

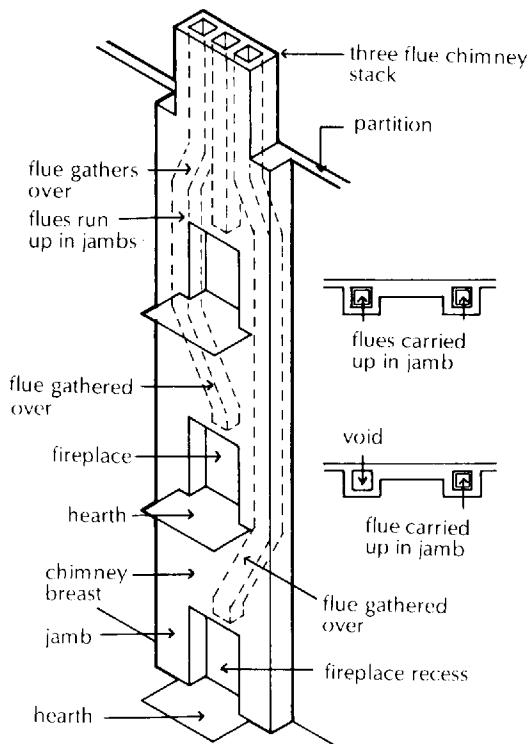
Liners should be jointed with fire-proof mortar and spaces between the liners and the brickwork of flues should be filled with a weak mortar or insulating concrete.

The inner leaf of the majority of external cavity walls and most internal walls is built of concrete blocks for the sake of economy. It is convenient to build the chimney breast and chimney to open, inset fires in the same material. To match the dimensions and bonding of concrete blocks, a range of purpose made precast concrete flue blocks is made for building into concrete walls as flue and liner.

These blocks are made in depths to suit standard concrete building blocks and allow for bonding to the surrounding block walling.

Flue blocks are made of expanded clay aggregate concrete with a flue lining of high alumina cement and are rebated and socketed as illustrated in Fig. 194. Both straight and offset blocks are produced to suit bends in flue as shown in Fig. 194.

At the junction of the chimney and the roof, a corbel block is used to provide support for the chimney blocks and the brick facing to the chimney above roof level. The brick facing is used as protection against rain penetration and for appearance sake. A precast concrete coping block caps the chimney and provides a bed for the flue terminal.



**Fig. 195** Chimney to fireplaces on three floors.

Before the use of space heating by oil and gas central heating boilers became general it was common to construct inset, open fireplaces one above the other in multi-storey buildings. To accommodate flues being carried up at the sides of upper level fireplaces it was necessary to construct wide, projecting chimney breasts. An advantage of this arrangement was that the projecting breast would transmit some of the heat from flues to the inside.

As a massive brick pier the chimney breast would provide structural stability to external walls. The considerable weight of the massive chimney breast might also impose so heavy a weight on shallow foundations that settlement cracks appeared at the junction of the chimney breast and the surrounding less heavily loaded walling.

To bypass fireplace openings on floors above, it was necessary to construct flues so that they gathered over to one side to pass upper fireplaces as illustrated in Fig. 195. So that upper fireplaces could be located in the centre of the chimney breast, flues would be gathered over to pass the righthand or lefthand of upper fireplaces with the flue from the uppermost fireplace being carried up straight.

The inside of the traditional brick flue was lined with mortar as the flue was built to provide a smooth lining to assist the flow of combustion gases and air and facilitate sweeping flues to clear soot. This mortar lining of brick flues was termed *pargetting*. Current Building Regulations call for liners to flues.

When gas burning open fires and gas fired appliances are connected to existing unlined brick built flues it is necessary to line the flue with flexible stainless steel liners that are drawn up the flue and connected to the appliance and a terminal.

## Factory made insulated chimneys

As an alternative to constructing a flue for solid fuel burning open fires, room heaters and stoves a purpose made, factory made, insulated chimney may be used. These chimneys are made specifically to be freestanding inside buildings where the appearance of an exposed chimney is acceptable. Because of the neat, unobtrusive appearance and considerable cost of these chimneys they are used freestanding both in new and old buildings.

The advantages of these chimneys are their comparatively small cross section, ease of installation, high thermal insulation which conserves heat, and smooth faces to encourage draught and facilitate cleaning. These flue sections require some support at roof and intermediate floor levels and can be fixed anywhere in rooms.

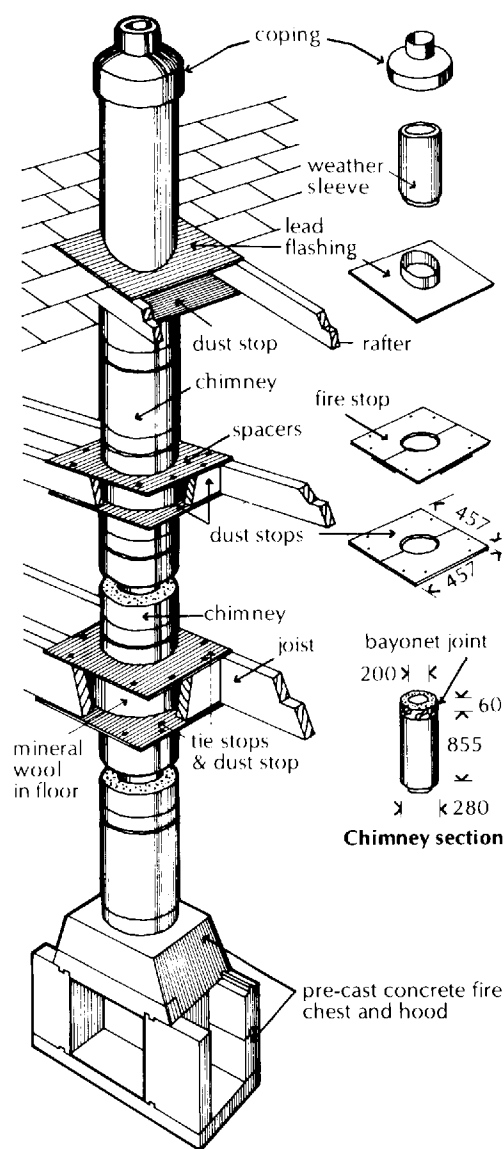


Fig. 196 Factory built insulated chimney.

### Proximity of combustible materials to chimneys

These factory made chimneys are made in sections that have socket and spigot ends that lock or are clamped together. These sections have stainless steel inner linings and either stainless steel or galvanised steel outer linings around a core of mineral insulation that conserves heat and prevents condensation in the flue. Because of the insulation and construction of these flue sections, structural timbers may be as close as 50 mm to the outside of the flue, which avoids the need for trimming timbers and facilitates supporting the chimney at floor and roof level. Figure 196 is an illustration of factory made chimney sections and fittings.

The cylindrical flue sections are joined with socket and spigot ends that are locked together with a bayonet locking joint. Where the chimney passes through timber floor and roofs, metal fire stop plates, that fit around the chimney, are nailed to the underside and top of the joists around the flue and to timber dust stops nailed between the joists. Mineral wool fibre is packed around the flue sections and the joists and dust stops.

At roof level a lead flashing dressed under the covering and around the flue fits into the spigot end of a weather sleeve section on to which a coping cap is fitted.

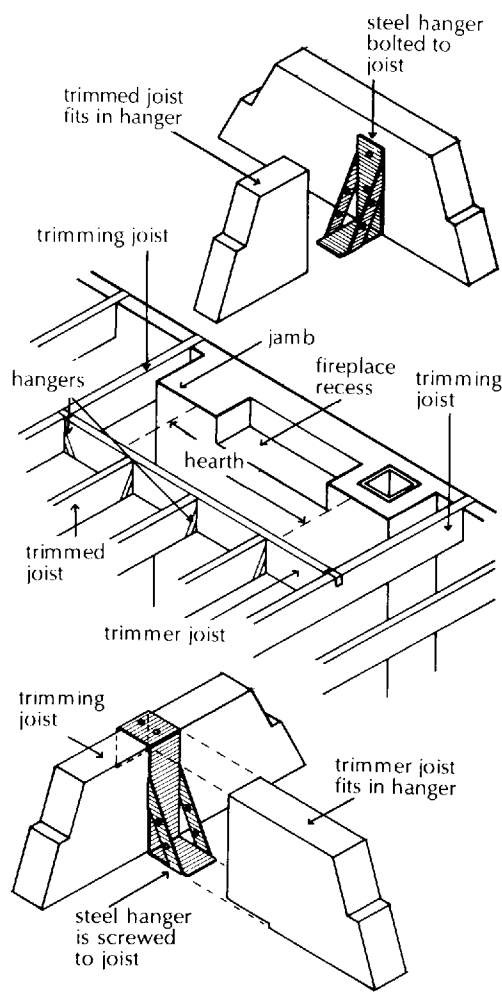
Precast, fire resisting concrete sections are used to construct a fire chest for freestanding inset open fires or room heaters. The fire chest comprises a hearth, sides, back and hood on to which the flue sections fit.

Because of the effective insulation between the outer and inner linings of these sections there is little likelihood of the temperature of the outside of the liners being sufficiently hot to cause burns, if touched.

Combustible materials such as timber floor joists and timber rafters should be separated from flues in brick or blockwork chimneys and fireplace recesses to minimise the possibility of them becoming so hot as to catch fire.

The practical guidance in Approved Document J to the Building Regulations recommends that timber, a combustible material, be at least 200 mm from a flue and 40 mm from the outer surface of a brick or blockwork chimney or fireplace recess unless it is a floorboard, skirting, dado or picture rail, mantelshelf or architrave. Metal fixings in contact with combustible materials should be at least 50 mm from a flue.





**Fig. 197** Trimming floor with metal hanger fixings.

So that a solid incombustible hearth, of concrete, may be formed inside and in front of a fireplace recess in an upper timber floor it is necessary to trim the floor timbers around the hearth. So that no combustible material is closer than 200 mm to a flue it is necessary to build in the ends of trimming joist each side of the chimney breast as illustrated in Fig. 197. The trimmer joist that supports the ends of the trimmed joists is supported by the trimming joists.

The concrete hearth may be a precast concrete slab that is built into the walls surrounding the fireplace recess and supported by a steel shelf angle bolted to the trimmer joist or cast in situ on temporary boarding and supported by a shelf angle bolted to the trimmer joist.

Timber cradling pieces are fixed each side of the projecting hearth to provide support and fixing for the ends of floor boards running into the side of the hearth. These cradling pieces are supported on steel corbel plates built into the chimney breast and the trimmer.

So that there is a strong, secure joint between the trimming, trimmer and trimmed floor joists either pressed steel hangers or the traditional handcut timber joints are used.

For the sake of economy, galvanised steel joist hangers are much used today. The ends of the trimmer joist are supported by steel hangers that fit around the top and sides of the trimming joist to which they are screwed. The trimmer joist end fits into the hanger to which it is nailed. The ends of the trimmed joist may be supported by similar joist hangers or by a joist hanger that is screwed to the side of the trimmer joist as illustrated in Fig. 197.

These steel joist hangers provide a perfectly satisfactory means of support and fixing for timber floor joists.

The traditional handcut joints between timber floor and roof joists were the tusk tenon and the housing joint. The tusk tenon joint is cut with a tenon that fits to a mortice cut on the centre line of the depth of the joists being joined. In this position the mortice will least weaken the strength of the timber which is cut. A tusk and a horn bear in the joined timber and the protruding tenon is secured by a wedge as illustrated in Fig. 198 to make a secure joint.

As it is not practical to use a tusk tenon joint between the trimmed and trimmer joists because of the concrete hearth, a half depth housed joint is used. The ends of the trimmed joists are half depth, square or dovetail housed in matching housings cut in one side of the trimmer joist as illustrated in Fig. 199. The advantage of the dovetail joint is that the dovetail locks the end of the joist firmly in place.

A skilled carpenter can cut and assemble these handcut joints in little time and there is no appreciable cost saving in using steel joist hangers.

Where the outside dimensions of a chimney stack, such as the one flue stack shown in Fig. 188, are less than the spacing of the roof

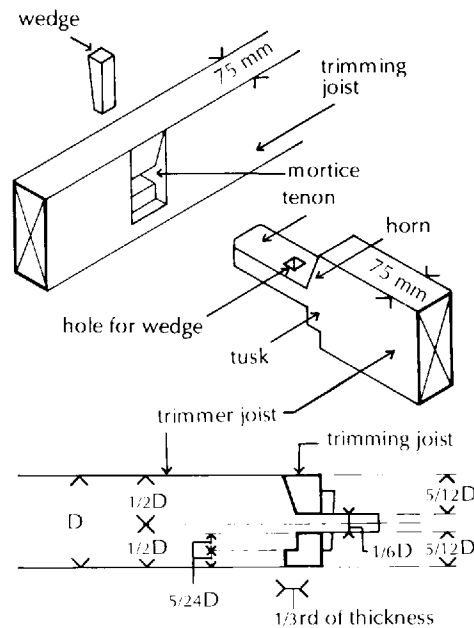


Fig. 198 Tusk tenon joint.

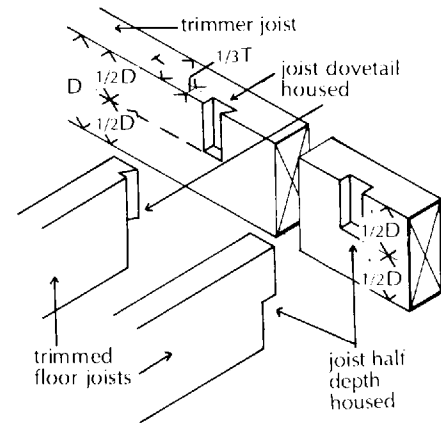


Fig. 199 Methods of housing trimmed joists to trimmer.

trusses, there is no need to trim either the roof or the ceiling timbers around the chimney. Where a chimney stack is wider overall than the spacing of the trusses or rafters it is necessary to trim the timbers around the stack using either timber joints or hangers.

## Chimney stacks above roof

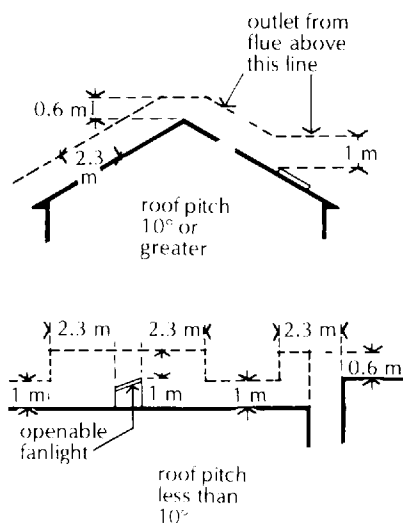


Fig. 200 Outlets from flues.

Chimney stacks are raised above roofs to encourage the products of combustion to rise from the flue to the open air by avoiding down draught. The practical guidance in Advisory Document J to the Building Regulations sets minimum dimensions for the outlet of flues above roof level as illustrated in Fig. 200.

For roofs pitched at less than  $10^\circ$  the outlet of any flue in a chimney or flue pipe should be at least 1 m above the highest point of contact between the chimney or flue pipe, and for roofs pitched at  $10^\circ$  or more should be 2.3 m measured horizontally from the roof surface.

The outlet of any flue in a chimney or flue pipe should be at least 1 m above the top of any openable part of a window or skylight or any ventilator or similar opening which is in the roof or external wall and is not more than 2.3 m horizontally from the top of the chimney or flue pipe.

The outlet of any flue in a chimney, or any flue pipe, should be at least 600 mm above the top of any part of an adjoining building which is not more than 2.3 m horizontally from the top of the chimney or flue pipe.

For the sake of strength and stability the practical guidance in Approved Document A to the Building Regulations sets the least height of masonry chimneys at 4.5 times the least width of chimneys

## Chimney pots, terminals

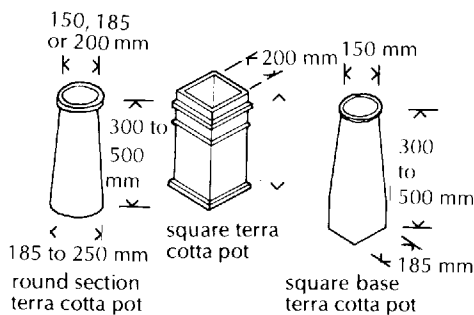


Fig. 201 Flue terminals (chimney pots).

measured from the highest point of intersection of roof and chimney to the top of chimney pots or terminals, where the density of the masonry is greater than  $1500 \text{ kg/m}^3$ .

The traditional method of finishing the top of a brick chimney stack above roof is with a chimney pot. Either round or square section chimney pots are used. The purpose of the chimney pot is to provide a smooth sided outlet to encourage the outflow of combustion gases to outside air and to provide a neat terminal to stacks which, with cement and sand flaunching around the pots, will provide resistance to weather. Some typical terra cotta (burned earth) chimney pots are illustrated in Fig. 201.

The internal dimensions of these pots should be similar to that of the flue and the pots should be at least 150 mm high. The pots are bedded in cement and sand on the stack and flaunched around in coarse sand and cement and weathered to slope out as illustrated in Fig. 204.

A variety of chimney pots and galvanised steel terminals is produced with louvred sides, horizontal outlets and metal terminals designed to rotate with changes of wind direction to minimise down draught in flues, caused by deflection of wind due to adjoining buildings, trees and higher adjacent land. These special pots and terminals are generally used in the hope of preventing down draught in flues, more in hope than anticipation.

## Resistance to weather

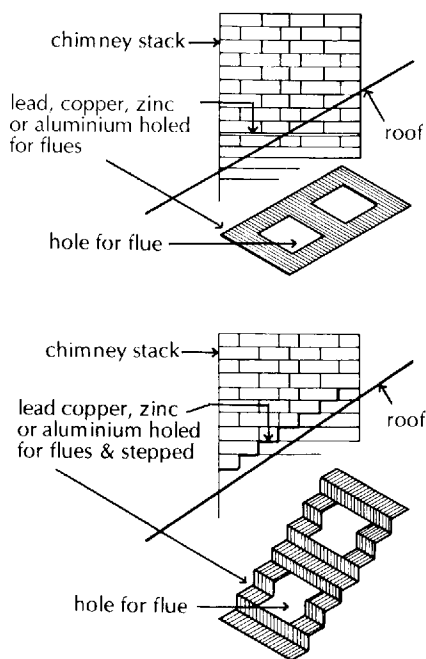


Fig. 202 Damp proof courses in chimney stacks.

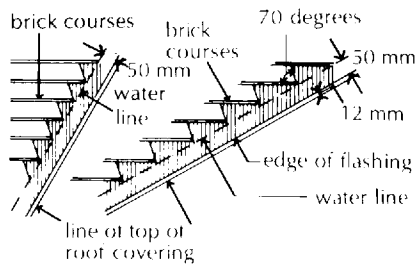
A brick or masonry chimney stack above roof level is exposed to wind-driven rain and liable to become saturated with water, particularly in exposed positions. A chimney stack constructed with porous brick or stone may become so saturated that the stack below roof level becomes damp where the natural cycles of wet and dry weather do not cause sufficient evaporation of water.

For exposed positions, chimney stacks built of porous bricks or stone should be separated from the chimney below roof level by some form of damp proof course (dpc). A sheet of lead, holed for flues, should be built in to the chimney stack either in a horizontal course of brick or stone or built in and stepped to coincide with stepped lead flashings as illustrated in Fig. 202.

With the horizontal dpc there will be a small area of brick or stone work above and below the dpc where some dampness may occur. The stepped dpc, which avoids this, involves a considerable degree of additional labour in dressing the lead to shape and cutting of brick or stone to match the steps.

In sheltered positions where more dense and less absorbent brick or stone is used it is probably unnecessary to use a dpc.

## WEATHERING AROUND CHIMNEYS



Setting out stepped apron flashing

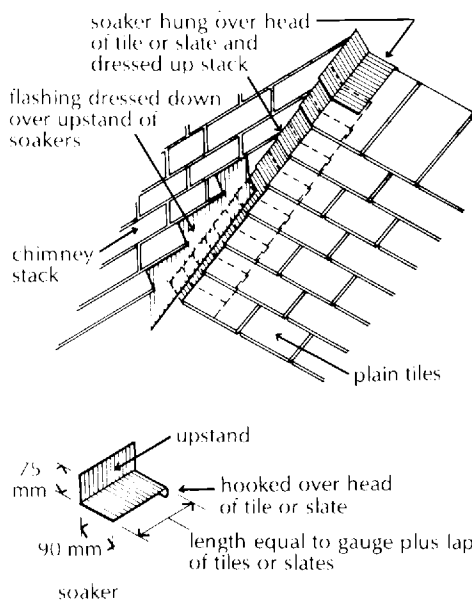


Fig. 203 Stepped flashing and soakers.

At the junction of roof coverings and chimney stacks it is necessary to provide some form of weathering to prevent the penetration of rain into the roof.

The cheapest and most commonly used method of weathering around chimney stacks is to form a fillet of coarse, sharp sand and cement spread and levelled up to the stack and down on to the tile or slate roof covering. The disadvantages of this system of weathering are that the rigid cement and sand fillet will not accommodate the inevitable slight movements of the roof due to wind pressure and moisture and thermal movements and the cement fillet will suffer drying shrinkage and crack.

The best method of excluding rain is to form and fix a system of lead flashings that will accommodate movement between roof and stack.

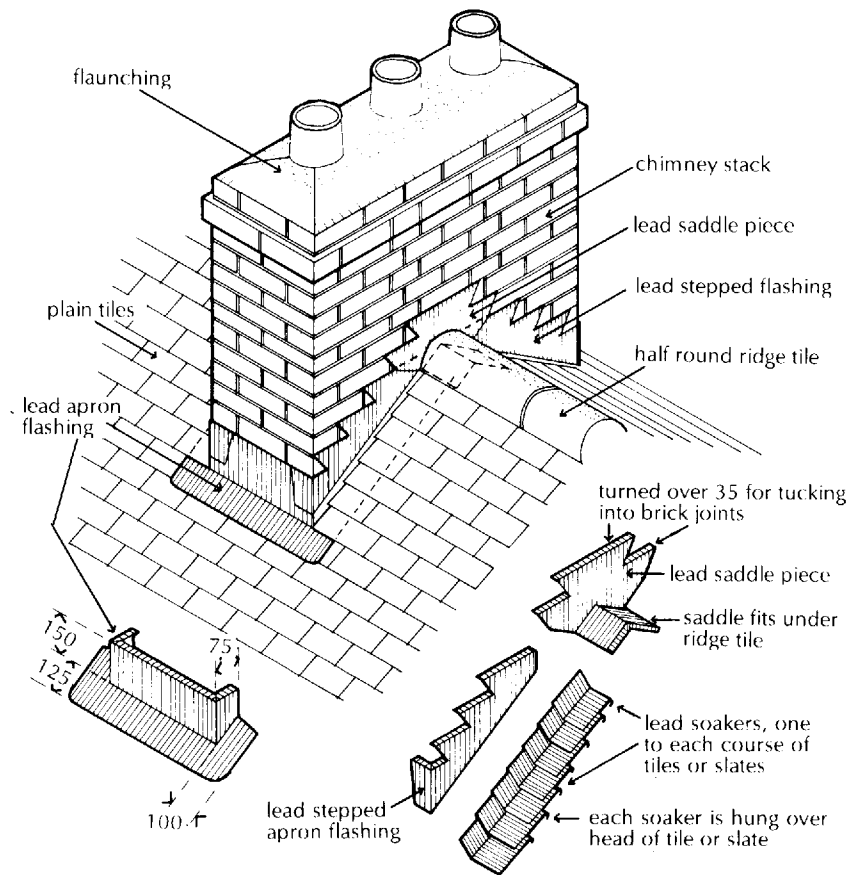
The junction of pitched roof coverings and brick or stone stacks is weathered by stepped lead flashings that are cut for building into horizontal joints in the form of steps and cut for dressing over lead soakers that are hung over the head of each tile or slate and dressed up under the stepped flashing as illustrated in Figs 203 and 204. The stepped apron flashing overlaps the upstand of soakers by 50 mm and soakers overlap one another by the gauge of the roof covering. The edge of each step of the flashing is wedged into a raked out horizontal brick joint and pointed in mortar.

At the junction of the ridge of the roof and a stack a saddle piece is used and at the front of a stack, which is at right angles to the slope of the roof, a front apron flashing is used as illustrated in Fig. 204. These flashings are tucked into horizontal brick joints, wedged and pointed.

At the junction of side lap roof tiles and a chimney stack the stepped lead flashing is dressed down over the tiles to exclude rain-water as illustrated in Fig. 205. Here there is no need for soakers as the flashing dressed over the roll will suffice.

At the junction of a roof slope down towards a chimney stack it is necessary to form a lead back gutter to collect water running down the slope and divert it to run each side of the stack. The back gutter is shaped out of one sheet of lead to form an upstand, gutter bed and apron to dress under the roof covering as illustrated in Fig. 205. The upstand of the back gutter is weathered by a cover flashing that is tucked into a horizontal brick joint, wedged and pointed and dressed down over the back gutter upstand. The particular advantage of lead as weathering to stacks is that it is malleable and can be shaped to the form of a back gutter without tearing or suffering appreciable loss of thickness.

Lead is the metal, in sheet form, best suited to use as weatherings to stacks and roofs. It is used in thicknesses of number or code 5 or 4 which numbers coincide with the old 5 lb and 4 lb weight of lead.

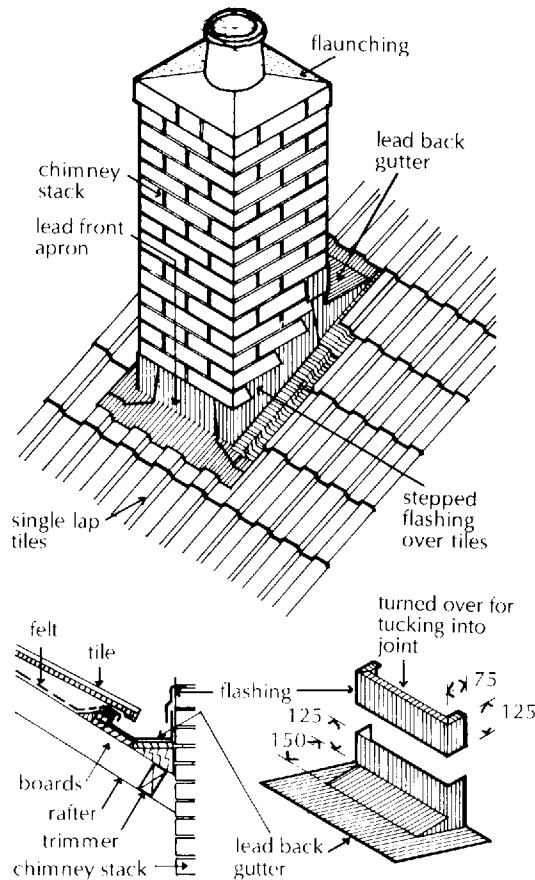


**Fig. 204** Lead flashings around chimney stack.

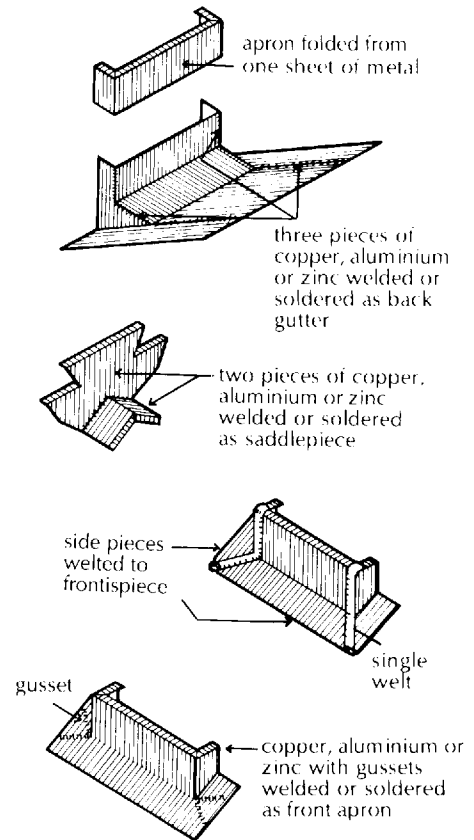
The other metals in sheet form that may be used as weathering around chimney stacks are copper, aluminium or zinc. Copper, which is moderately malleable, suffers the disadvantage that it forms a blue oxide of copper in combination with water, which will be washed on to roof coverings to form an unsightly blue stain. Aluminium is moderately malleable and unlikely to cause stains. Zinc sheet is stiff and difficult to bend and shape as compared to other metals. Its low cost is outweighed by the difficulty in shaping the sheet.

For use as weatherings around chimney stacks above roof, copper, aluminium and zinc sheet are folded to shape around the stack and the back gutter and front apron are completed with a welded or soldered joint as illustrated in Fig. 206. Soakers are folded from metal sheet without difficulty. Because of the difficulty of shaping these sheets of metal and the complication of joints necessary they are much less used than lead sheet.

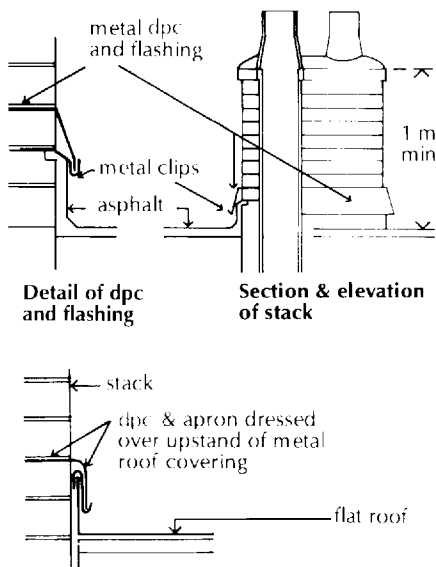
At the junction of flat roofs and chimney stacks the sheet metal, asphalt or built up felt roofing is dressed up to the sides of the stack with an upstand of about 150 mm.



**Fig. 205** Single flue chimney stack through one slope of roof.



**Fig. 206** Non-ferrous metal flashings to chimney stack.



**Fig. 207** Weathering of chimney stack and flat roofs.

Asphalt is run up against the stack sides as an upstand that is continued into a groove, purpose cut in a brick joint. The hot asphalt is worked into the groove and the joint later pointed with mortar. This skirting and tuck-in may be a satisfactory weathering for the useful life of asphalt. As a safeguard, a lead flashing may be tucked into a brick joint and dressed down over the asphalt skirting as illustrated in Fig. 207 against the possibility of the top of the asphalt skirting cracking due to movement of the roof relative to the stack.

Sheet metal roof coverings of lead, copper or aluminium are dressed up to the sides of the stack with a 150 mm upstand.

The top edge of the upstand is protected by a flashing, of the same metal as the coverings, which is tucked and wedged into a brick joint and dressed down over the upstand. To prevent the apron flashing being blown up in high wind, strips of the sheet are folded over the top of the upstand and the lower edge of the upstand at 400 mm centres.

With felt roof covering the felt is dressed up to the sides of the stack as a 150 mm upstand and a sheet metal apron flashing is dressed down over the upstand.

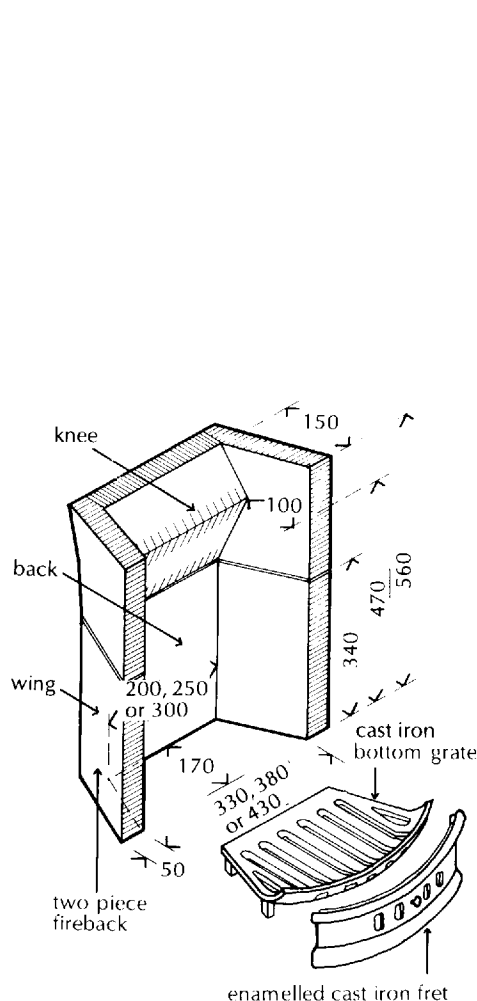
## Inset open fireplace

An inset open fire is formed in a recess inside a chimney breast or wall under a flue built in the chimney breast. The fire is inset in a recess to contain the burning fuel and is open to transfer heat to the room by radiation and convection and for the benefit of a view of the fire.

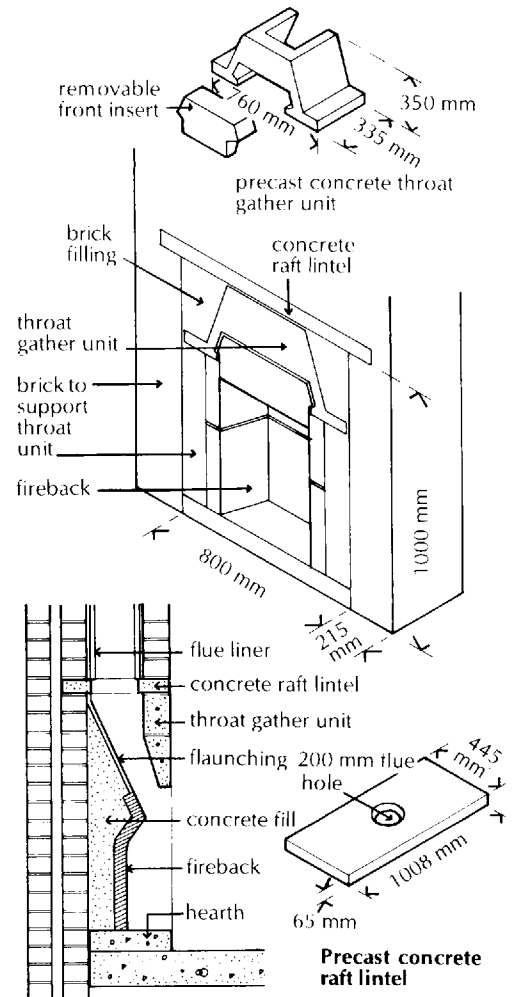
Wood burning open fires are often laid to burn inside the fairface brick jambs and back of a recess to provide room for the considerable bulk of wood necessary to provide sufficient heat, particularly for the larger rooms.

Inset open fires for the normal domestic room are generally for burning coal on an iron grate to contain the burning coals and provide some draught of air under and through the coals.

The traditional grate is set in a fireback. Figure 208 is an illustration of a typical fireback, grate and fret. The fireback is made from fire clays, which are clays that contain a high proportion of sand with



**Fig. 208** Fireback, grate and fret for open fire.



**Fig. 209** Precast concrete throat gather unit.

some alumina. The clay is moulded, dried and fired in a kiln. The burned fireclay is able to withstand considerable heat without damage and is used for that reason. The fireback illustrated in Fig. 208 is a standard two-piece fireback for 350, 400 and 450 mm wide open inset fires. The fireback may be in one, two, four or six pieces, the four and six piece backs being made to facilitate replacing an existing damaged fireback.

The fireback is set in position on a level concrete back hearth as illustrated in Fig. 209, and vermiculite concrete fill is cast behind it as insulation and flaunching up to the flue.

To reduce the width of the flue to that of the fireback, brickwork is constructed to gather in, in offset brick courses from the top of the fireback to the width of the flue above. As an alternative a precast concrete throat gather unit may be used. The unit is made in two pieces as a throat unit and a front insert as illustrated in Fig. 209.

When the fireback has been set in place, brickwork is built up in the spaces each side of the fireback and the recess. The throat gather unit is then bedded on the fireback and jamb filling brickwork and the front inset set in place as illustrated in Fig. 209. Brickwork filling is built up between the top of the throat unit and the raft lintel.

The advantage of the throat gather unit is that it provides a smooth surface for the draught of combustion gases up the flue to accelerate updraught.

To support the brickwork of the chimney breast over the fireplace recess a precast, reinforced concrete raft lintel is often used. The lintel, illustrated in Fig. 209, is holed for the flue and is built in, bearing on the jambs of the fireplace opening.

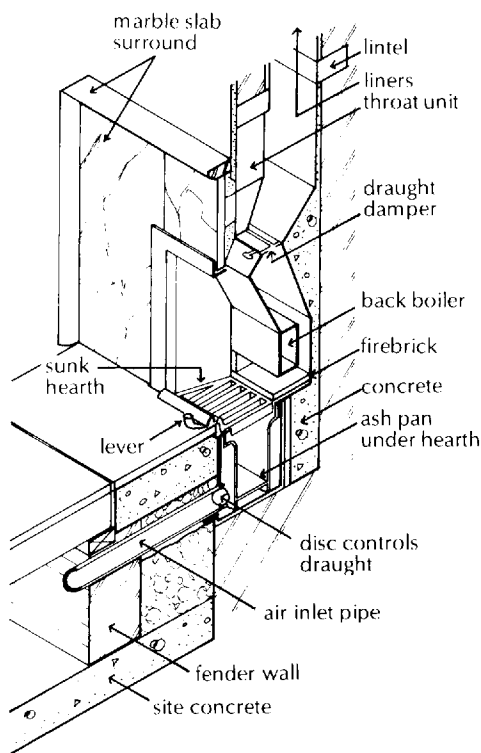
The removable cast iron grate and stove enamelled fret are set in place inside the fireback. The purpose of the fret is to contain the hot embers that fall through the grid of the grate and to adjust the draught through the grate by opening or closing a sliding plate cover to the holes in the fret. This provides a facility to create maximum draught through a newly lit or freshly fuelled fire.

For appearance a fire surround is usually fixed in front of the fireplace opening as illustrated in Fig. 210. The surround is usually set in a chromium plated steel angle, fire frame and the surround may be of any incombustible material such as decorative stone or tiles bedded in cement and sand with the surround contained within a wood surround or returned into the wall.

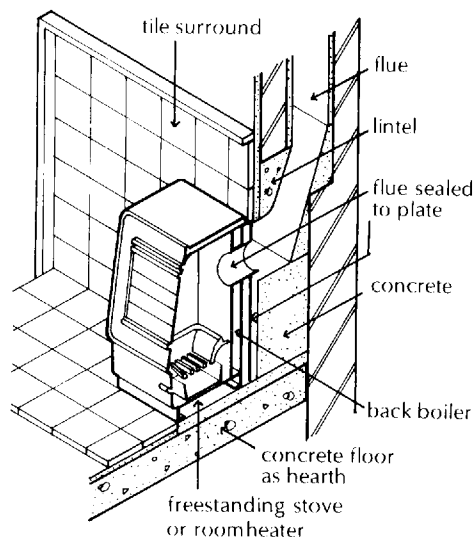
## **SUNK HEARTH OPEN FIRE**

The traditional open fire draws air from the room in which it is installed with the effect that there will be appreciable draughts of air from gaps around doors and windows when the fire is burning vigorously on a cold, clear day. Such draughts, of what is usually cold air, will cause discomfort to those around the fire and be wasteful of





**Fig. 210** Sunk hearth open fire.



**Fig. 211** Freestanding stove.

the heat generated by the fire in drawing air and heat up the chimney.

Where weatherseals are fitted around the opening parts of windows and doors there may well be an inadequate source of replacement air in rooms heated with open fires to the extent that the fire will not burn adequately due to lack of air for combustion.

A sunk hearth open fire is designed to draw air into the fire from outside, independent of the room that is heated. The loose, cast iron fire grate is placed over a sunken pit in which is an ash pan. Outside air is drawn from outside through a pipe laid under a hollow timber floor or below a solid concrete floor. The pipe is run under the floor to a balancing chamber from which pipes are run to the outside on opposite sides of the building.

Where the air inlet pipe connects to the pit below the hearth there is a disc, fitted to swivel inside the pipe and operated by a lever to control air intake. The loose grate can be lifted to take out the ash pan for emptying.

The sunk hearth illustrated in Fig. 210 is fitted with a back boiler, set in place with the fireback, to use heat from the fire that might otherwise be wasted, for heating hot water.

The efficiency of the sunk hearth fire depends on a draught of warmed air flowing up the flue to create reduced air pressure that will cause air from outside to be drawn through the underfloor pipes that should be as straight, short and large as practical.

Room heater, which is the term sometimes used to describe a freestanding stove, may as well be used to describe an electric bulb which is a form of heater. A cast iron stove, which was much used when room heating by solid fuels was more general than it is today, is illustrated in Fig. 211. For maximum efficiency in transferring heat to a room the stove should be freestanding so that energy in the form of heat is transferred by radiation and convection air currents around the whole of the outer surface of the stove.

The stove enamelled stove, illustrated in Fig. 211, is set on a projecting hearth with a steel flue pipe from the back of the stove passing through a hole in the steel register plate, fixed behind the stove, to the flue. A hinged door in the front of the stove is used to fuel the stove. This door is usually covered with a sheet or sheets of mica to provide an awareness of the glow of the fire. Many of the stoves were made with a back boiler that provided a source of heat for water, to augment the domestic hot water supply.

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## 5: Internal Finishes and External Rendering

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### PLASTER

Plaster is the word used to describe the material that is spread (plastered) over irregular and coarse textured wall and ceiling surfaces to provide a smooth level finish.

### History

During the many centuries before Portland cement first came into general use, in the latter part of the nineteenth century, lime was the material used as the matrix (binding agent) for plaster. The advantage of lime is that it is a cheap, readily available material that, used with sand and water for levelling undercoats and by itself with water as a smooth finish, is comparatively easy to spread and level as an interior wall and ceiling finish.

The disadvantage of the material is that it does not provide a hard surface resistant to knocks and over the years it loses strength and is liable to lose adhesion to surfaces on which it is applied.

From the beginning of the twentieth century the then new wonder material Portland cement largely replaced lime as the material used for undercoats of plaster. The advantage of cement is that it sets and dries to form a hard, dense surface coating, resistant to knocks. The disadvantage of cement for plaster is that it is more laborious to spread and level than lime and as it dries it shrinks fiercely and may develop cracks and lose adhesion to weak surfaces over which it is spread.

From the middle of the twentieth century gypsum first came into general use as a material for both undercoat and finish plaster and has by now to a large extent replaced both lime and cement. The advantage of gypsum is that it does not shrink on drying out and it forms a sufficiently dense surface to resist normal knocks. It is supplied pre-mixed for undercoats and is less messy to use than fine, dry lime and cement powder. Gypsum plaster is comparatively easy to spread and level.

The disadvantage of gypsum is that it is more expensive than lime or cement. The cost disadvantage of gypsum should be weighed against the advantages and the fact that the labour cost is appreciably greater than that of materials in plastering.

Old habits die hard and it is not uncommon for cement plaster to be used today on the basis that it forms a hard surface more resistant to knocks than is generally necessary and the mistaken belief that it effectively resists the penetration of damp through porous backgrounds such as brick.

## PLASTERING

Plaster is used to render, turn, an uneven surface into a smooth, level surface by plastering (spreading) a material over its surface. The initially wet material is spread and levelled over uneven backgrounds such as brickwork, and over lath fixed to the underside of timber floor joists so that as it hardens and dries it forms a smooth, level wall and ceiling finish.

The purpose of plaster is to provide a smooth, hard, level finish which can be painted for the sake of appearance and as a light coloured finish to gain the advantage of reflected daylight.

Fashions change and it is not uncommon today for one or all of the walls of rooms in modern houses to be finished with brick, block or stone exposed for the sake of the appearance of the materials or with the surface of brick and block wall painted.

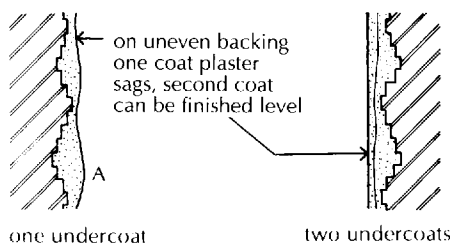
### Plaster undercoats and finish coat

The finished surface of plaster should be flat and fine textured (smooth). It would seem logical, therefore, to spread some fine grained material, such as lime or gypsum mixed with water, over the surface and trowel it smooth and level. The maximum thickness to which a wet, fine grained material can be spread and levelled is about 3 mm. The irregularities in the surface of even the most accurately laid brick or blockwork are often more than 3 mm and it would be necessary to apply two coats to achieve a satisfactory finish.

Instead of applying a fine grained plaster in two coats to irregular surfaces it is practice to spread some cheaper, coarse grained material that is easily spread as one or two coats to render the surface level and then finish with a thin coat of fine grained material to provide a smooth finish.

The coarse grained coat or coats of plaster are termed undercoats and the fine grained final coat a finish or finishing coat.

### Three coat plaster



**Fig. 212** The advantage of two undercoats.

Before the introduction and use of cement and, later, gypsum for use in plastering, lime was the material used. At the time most external walls were of solid brickwork. Many of the bricks then used were of irregular shape and size so that a solid wall finished flush externally had a particularly irregular inner face which required the use of two undercoats of lime and sand to produce a sufficiently level surface.

If one thick undercoat were spread and levelled on an irregular surface it would tend to sag, as illustrated by line A in Fig. 212, due to the weight of the still plastic, wet plaster. If, however, a thinner first undercoat is spread and allowed to harden, a second undercoat can be spread to take out variations in level as indicated in Fig. 212. The first undercoat was called the render and the second the float coat.

## **Two coat plaster**

Most brick and block external walls today are built as cavity walls with the inner leaf of regularly shaped bricks or blocks whose comparatively regular surface can be successfully plastered in two coats. one undercoat of cement and sand or more usually one gypsum undercoat and one gypsum finish coat.

## **Dubbing out**

Where some part of the surface of brick or block is particularly uneven it is practice to fill the hollows with undercoat plaster up to the general level of the wall face. This practice is termed dubbing out, ready for two coat plaster finish.

## **One coat plaster**

One coat plaster is gypsum plaster which combines the qualities of both undercoat and finish plaster in one product. The material, which is spread and built up by hand to a thickness of 11 to 13 mm thickness on brick and block backgrounds, is progressively trowelled to a reasonably level, smooth matt finish ready for decoration.

The material, which is mainly used as a do-it-yourself (DIY) plaster, can be harder work to apply than a two coat plaster.

## **MATERIALS USED IN PLASTER**

### **Lime plaster**

Lime is mixed with sand and water in the proportion of 1 of lime to 3 parts of sand by volume, with water for use as undercoat and by itself with water as a finish coat.

As lime plaster dries and hardens it shrinks and fine hair cracks may appear on the surface. To restrain shrinkage and to reinforce the plaster, long animal hair is included in the wet undercoat mix, 5 kg of hair being used for every square metre of the lime undercoat (coarse stuff). The resulting haired, coarse stuff is plastic and dries out and hardens without appreciable shrinkage and cracking. Three coat lime plaster is finished to a thickness of about 18 mm.

Lime plaster may be damaged by knocks and in time becomes dry and powdery. As lime is soluble in water it should not be used in damp or moist situations.

Lime plaster is used today in the restoration and preservation of ancient buildings. Many purists insist on the use of original materials in restoration work.

### **Cement plaster**

The properties of Portland cement were described in Volume 1. It is used as a fine grey powder which, when mixed with water, hardens to a solid, inert mass. It is mixed with sand and water for use as an undercoat for application to brick and block walls and partitions. It is used on strong backgrounds as 1 part of cement to 3 or 4 parts of clean, washed sand by volume.

A wet mix of cement and clean sand (sharp sand) is not plastic and requires a deal of labour to spread. It is usual, therefore, to add either lime or more usually a plasticiser to the wet mix to produce a material that is at once plastic and sets and hardens to form a hard surface. Usual mixes are 1 of cement, 1/4 lime to 3 of sand, 1 of cement, 1 of lime to 6 of sand or a mix of 1 of cement to 4 sand with a mortar plasticiser by volume.

### **Mortar plasticiser**

A mortar plasticiser is a liquid that, when mixed with water, effervesces so that tiny bubbles of gas that are generated act to cushion the sharp particles of sand and make the mix plastic and easy to spread.

Cement and sand undercoats are the cheapest in use today.

As an undercoat of cement and sand dries out, it shrinks fiercely and cracks may appear on the surface. In general the more cement used the greater the shrinkage. The extent of the cracking that may appear depends on the strength of the surface to which the plaster is applied and the extent to which the plaster binds to the surface.

For example, the surface of keyed fletton brickwork is strong and affords sufficient mechanical key to restrain shrinkage whereas the surface of lightweight blocks is not strong enough to restrain the shrinkage of cement rich mixes.

A cement and sand undercoat may be used on a backing of hard coarse textured brick and dense blocks. On other brick and block surfaces a mix of 1 of cement, 1/4 lime to 3 of sand may be used and on lightweight blocks a mix of 1 cement, 1 lime to 6 sand. A cement and sand undercoat with a gypsum finish will be spread to a thickness of about 12 mm.

### **Gypsum plaster**

During the last 70 years the use of gypsum plaster has increased greatly for both undercoat and finish plaster to the extent that it has largely replaced lime and cement.

The advantage of gypsum plasters is that they expand very slightly on setting and drying and are not, therefore, likely to cause cracking of surfaces.

Gypsum is a chalk like mineral. It is available as both natural gypsum, which is mined in areas all over the world, and as a synthetic by-product of major industries such as fossil fuelled power stations.

Gypsum is a crystalline combination of calcium sulphate and water ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ).

### **Hemihydrate gypsum plaster (plaster of Paris)**

When powdered gypsum is heated to about  $170^\circ\text{C}$  it loses about three quarters of its combined water and the result is described as hemihydrate gypsum plaster ( $\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$ ). This material is better known as plaster of Paris.

**Anhydrous gypsum plaster**

When gypsum is heated to a considerably higher temperature than 170°C it loses practically all its combined water and the result is anhydrous gypsum plaster.

**British Standard 1191**

British Standard 1191 Parts 1 and 2 cover the manufacture of all traditional and modern gypsum based plasters.

It is convenient to categorise gypsum plasters relative to their use as wall and ceiling plasters as casting, undercoat, finish, one coat and machine applied plasters.

**Casting plaster**

Finely ground hemihydrate gypsum (plaster of Paris) when mixed with water sets and hardens so quickly (about 10 minutes) that it is unsuitable for use as a wall or ceiling plaster. It is ideal for making plaster casts for medical casts and cast plaster work for buildings.

Wet plaster of Paris is brushed into moulds to provide cornices and other decorative plaster work. The wet plaster is usually reinforced with open weave hessian and is generally referred to as fibrous cast plaster or fibrous work.

**Undercoat plaster**

To provide a solid, true background as an undercoat for finish plaster for wall and ceiling surfaces, pre-mixed gypsum plaster is the generally preferred material used today.

**Retarded hemihydrate gypsum plaster**

The gypsum used for undercoats is retarded hemihydrate gypsum in which a retarding agent is added to plaster of Paris to delay the setting time for 1½ to 2 hours to allow time for spreading and levelling the wet material as undercoat.

For general use as an undercoat the retarded hemihydrate gypsum powder is mixed with lightweight aggregates, such as expanded perlite or vermiculite, as a dry mix powder which is delivered to site in bags as pre-mix undercoat.

**Pre-mix gypsum undercoat**

The advantage of this material is that the pre-mix avoids the messy, wasteful operation of mixing dry powdered lime or cement with sand. The wet mix is comparatively easy to spread and level and the lightweight aggregate gives a small degree of thermal insulation. A disadvantage of the material is that the lightweight aggregate may not provide adequate resistance to damage by knocks.

This material is applied as one undercoat to a finished thickness of 8 to 11 mm.

In addition to the standard lightweight aggregate undercoat, other gypsum undercoat plasters are produced for specific background and use situations.

**Bonding undercoat**

Where the undercoat plaster is to be applied to a surface with particularly low suction, which does not readily absorb water, gypsum bonding undercoat is formulated to provide adequate adhesion.

**High impact undercoat**

In some situations where it is anticipated that rough or careless usage may damage standard undercoat plaster, high impact gypsum undercoat is used. A dense aggregate such as grains of silica are used in the pre-mix in lieu of the usual lightweight aggregate to provide improved resistance to knocks.

**Finish plaster**

Finish plaster is powdered, retarded hemihydrate gypsum by itself for use as a thin finish coat for both gypsum undercoats and to plasterboards. Mixed with water the plaster is spread and finished to a thickness of about 2 to 5 mm and sets in about 1 to 2 hours. This plaster, which is polished to a smooth surface, is also used as a finish to cement and sand undercoats.

**Anhydrous gypsum plaster**

Anhydrous gypsum plaster was commonly used as a thin finish coat to cement based undercoats. The powdered gypsum is mixed with a mineral sulphate to accelerate its set, which otherwise would be so slow as to make it unsuitable for use as a finish plaster.

A characteristic of this gypsum plaster is that it can be brought back (retempered) by sprinkling the stiff surface to make it plastic for trowelling smooth. Because of its characteristic of being brought back, this finish is unsuited for use in damp or moist situations. This finish is less used than it was.

**One coat gypsum plaster**

One coat plasters are retarded hemihydrate plasters which combine the properties of an undercoat and a finish coat. One coat is applied to a thickness of up to 20 mm as an undercoat. As the plaster begins to set (stiffen) it is sponged with water and trowelled to bring the fine particles to the surface so that it may have a finish comparable to that of a separate finish coat.

Because of the considerable labour required to build up and level the surface, this plaster is not extensively used.

**Machine applied gypsum plaster**

Machine applied, or projection, plasters are one coat gypsum plasters designed to provide a longer setting time to allow for mixing, pumping, spreading and trowelling. The material is mixed with water, pumped and applied to the wall by a projection machine which effectively halves the application time it would take to spread by hand.

As the wet plaster covers the wall it is treated in the same way as one coat plaster by trowelling level and smooth.

Because of the additional labour in mixing and pumping and the necessary work of cleaning equipment after use, this type of plaster may be most economically used on large flat areas of wall.

## **BACKGROUND SURFACES FOR PLASTER**

The surface of walls to be plastered will affect the type of plaster used and its application.

The surface of rough textured bricks and concrete blocks and the face of keyed fletton bricks afford a key for the mechanical adhesion of plaster to the background wall. As the wet plaster undercoat is spread and pressed into the surface, wet plaster fills the irregularities and the key in flettons so that as it hardens it forms a mechanical key to the background.

### **Key for plaster**

With smooth faced bricks or blocks the mortar joints should be raked out some 12 mm, as the wall is built, to provide a key for plaster. An advantage of the key is that it will restrain shrinkage of cement based undercoats.

### **Suction**

Dense, smooth wall surfaces such as concrete and machine pressed bricks do not readily absorb water to the extent that a normal wet plaster will not adhere as it is spread, through lack of suction. The word suction is used to describe the degree to which a surface will absorb water and so assist in the adhesion of plaster to a surface.

Some lightweight concrete blocks readily absorb water and have high suction to the extent that wet plaster applied to them may lose so much water that it is difficult to spread and may not fully set due to loss of water. Suction may be reduced by spraying the surface with water prior to plastering or by the use of a liquid primer.

The most straightforward way of testing the suction of a surface is to spray it with water to judge the degree of absorption of water. There are liquid pre-treatments that can be applied to control the suction of surfaces.

### **PVA bonding agent**

There are two main types of treatment to improve the adhesion of plaster to surfaces with low suction, such as concrete, to avoid the laborious process of hacking the surface to provide a key.

The first is based on polyvinyl acetate (PVA) which is brushed or sprayed on to the surface. The plaster is applied before the PVA has fully dried and is still tacky. The tackiness provides the bond.

### **Polymer bonding agent**

The second pre-treatment is polymer based and incorporates silica sand. Once the polymer is fully dry the plaster is applied and gains bond through the silica grains and does not, therefore, depend on applying plaster as soon as the bonding agent is tacky.



## Reinforcement for angles

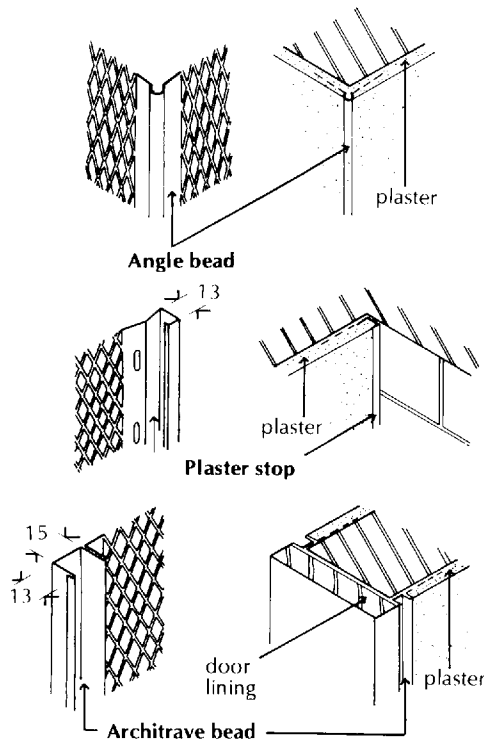


Fig. 213 Metal beads and stops for plaster.

## PLASTER FINISHES TO TIMBER JOISTS AND STUDS

### Fir lath

Where suction is high, as with lightweight blocks, the suction may be controlled by spraying with water or by spraying the surface with a liquid primer designed for the purpose.

A range of galvanised steel beads and stops is made for use with plaster and plasterboard as reinforcement to angles and stops at the junction of wall and ceiling plaster and plaster to other materials.

An angle bead is pressed from steel strip to form reinforcement to angles. The bead has expanded metal wings, as shown in Fig. 213. The wings of the bead are bedded in plaster dabs each side of the angle. The bead is then squared and plaster run up to it (Fig. 213).

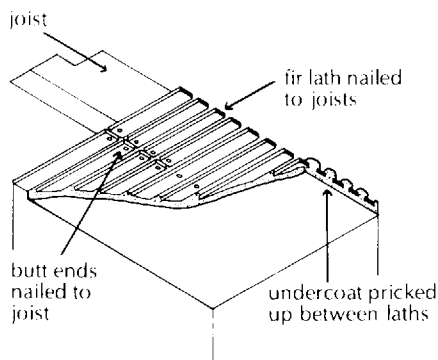
A metal stop with an expanded metal wing is pressed from steel strip and used as a stop to make a neat finish at the junction of plaster with other materials at angles, skirtings and around doors and windows, as illustrated in Fig. 213. The stop is either bedded in plaster or nailed to timber and the plaster is run up to the stop. These stops make a neat, positive break at junctions that would otherwise tend to crack or require some form of cover mould or bead to mask the joint. They are particularly useful at the junction of ceiling plaster or board on timber joists and wall plaster or fairface finishes where a crack might open at the junction of plaster to another material which would be untidy.

Another bead or stop is designed for use at the junction of plaster and door and window frames to provide a definite break in surface between different materials, as illustrated in Fig. 213. The stop is either bedded in plaster dabs or nailed to wood.

The advantage of these beads is that they act as a break at the junction of dissimilar materials where they will mask any crack that may open. They are used instead of architraves.

The traditional method of forming a level finished surface to the ceiling of timber floors and roofs and to stud partitions was to spread plaster over timber lath. This laborious procedure has for the last 70 years been abandoned in favour of the use of gypsum plasterboard.

Before the twentieth century the usual method of preparing timber ceilings and timber stud walls and partitions for plaster was to cover them with fir lath spaced about 7 to 10 mm apart to provide a key for the plaster. The usual size of lath is 25 mm wide by 5 to 7 mm thick, in lengths of 900 mm. The lath is either split or sawn from Baltic fir (soft wood). Split lath is usually described as riven lath and is prepared by splitting along the grain of the wood. Because the grain of the wood is never absolutely straight neither is riven lath, so that when it is fixed the spaces left between the laths as a key for the plaster are not uniform. This may prevent the plaster being forced



**Fig. 214** Fir lath and plaster.

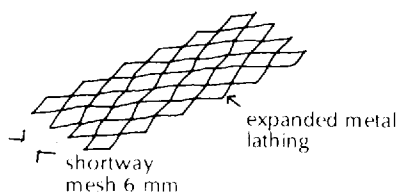
between the laths and it will not therefore bind firmly to them. Sawn lath, on the other hand, is uniformly straight and can be fixed with uniform spaces to give a good key for plaster. Fir lath must be adequately seasoned and free from fungal decay. The fir lath is nailed across the joists or timber studs. Obviously the ends of the laths must be fixed to a joist or stud, as illustrated in Fig. 214, and the butt end joints of laths staggered to minimise the possibility of cracks in the plaster along the joints.

Fir lath is covered with three coats of plaster. The first coat is spread and forced between the lath so that it binds to it. This coat is described as pricking up. A second undercoat, termed the float coat, is spread and finished level and then covered with the finish or setting coat.

Before the twentieth century the undercoats consisted of haired coarse stuff (1 part lime to 3 parts sand, with hair) gauged with plaster of Paris, and the finishing coat of lime and water gauged with plaster of Paris. The purpose of the gauge (addition of a small amount) of plaster of Paris is to cause the material to harden more quickly so that vibration due to the applications of the next coat, or vibrations of the floor above, will not cause the plaster to come away from the lath before it is hard.

The cost of fir laths and three coats of plaster today is about three times that of a plasterboard finish and in consequence is less used than it was other than for restoration work.

## Metal laths (EML)



**Fig. 215** Expanded metal lathing.

This lath is made by cutting thin sheets of steel so that they can be stretched into a diamond mesh of steel, as shown in Fig. 215. This lath is described as EML (expanded metal lath). The thickness of the steel sheet which is cut and expanded for plasterwork is usually 0.675 mm and the lath is described by its shortway mesh. A mesh of 6 mm shortway is generally used for plaster. To prevent expanded steel lath rusting it is either coated with paint or galvanised. As a background for plaster on timber joists and studs, the lath, which is supplied in sheets of 2438 × 686 mm, is fixed by nailing with galvanised clout nails or galvanised staples at intervals of about 100 mm along each joist or stud. During fixing, the sheet of lath should be stretched tightly across the joists. Edges of adjacent sheets of the lath should be lapped at least 25 mm.

Metal lath was originally used as a substitute for fir lath. It may be used as a base for three coat lime plaster. It was much used in the late nineteenth and early twentieth century as a base for cement and sand undercoats with a gypsum finish to ceilings. It was, and still is, used to some extent as a background for ceilings suspended below concrete floors and as a base for shaped, decorative plaster.

## GYPSUM PLASTERBOARD

Gypsum plasterboard consists of a core of set (hard) gypsum plaster enclosed in and bonded to two sheets of heavy paper. The heavy paper protects and reinforces the gypsum plaster core which otherwise would be too brittle to handle and fix without damage. Plasterboard is made in thickness of 9.5 mm, 12.5 mm, 15 mm and 19 mm for use either as a dry lining or as a background for plaster in boards of various sizes.

Plasterboard is extensively used as a lining on the soffit (ceiling) of timber floors and roofs and on timber stud partitions. The advantage of this material as a finish is that it provides a cheaper finish and can be fixed and plastered more speedily than lath and plaster. All gypsum plasterboards have inherently good fire resisting properties due to the incombustible core. The disadvantages are that, because it is a fairly rigid material, it may crack due to vibration or movement in the joists to which it is fixed, and it is a poor sound insulator. Many types of gypsum plasterboard are made for specific applications as dry linings.

### Gypsum wallboard

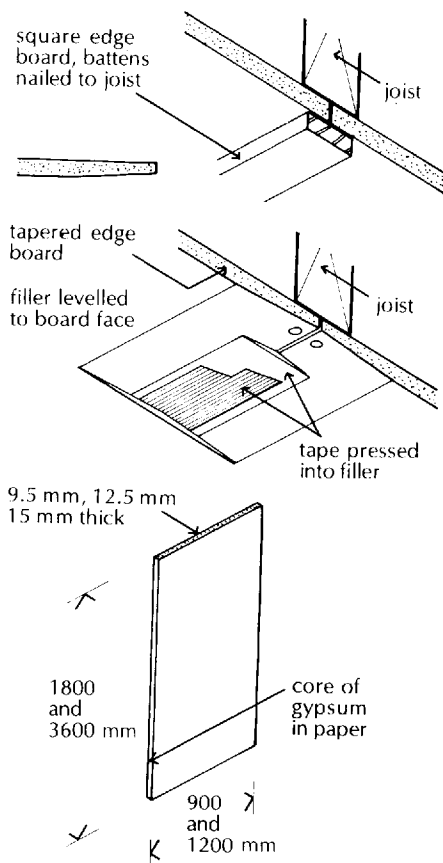


Fig. 216 Gypsum wallboard.

Gypsum wallboard, which is the most commonly used board, is principally made for use as a dry lining wallboard to timber or metal stud frames with the joints between the boards filled ready for direct decoration.

The boards have one ivory coloured surface for direct decoration and one grey face. The boards are 9.5, 12.5 and 15 mm thick, from 900 mm wide and up to 3600 mm long as illustrated in Fig. 216. The length of the boards is chosen as a multiple of standard timber joist or stud spacings such as 400 or 450 mm to minimise wasteful cutting of boards.

The boards are made with two different edges as illustrated in Fig. 216, tapered for smooth seamless jointing and square for cover strip jointing.

Wallboard is fixed to timber or metal supports with its length at right angles to the line of joists or studs. Timber or metal noggins are fixed between supports to provide support and fixing for the ends of boards which do not coincide with a support. Noggins are short lengths of timber, 50 × 50 mm in section, nailed between supports.

The boards are fixed with galvanised nails, 30 mm long for 9.5 mm and 40 mm long for 12.5 mm thick boards, or self tapping screws for metal studs. Nails and screws should be driven home to leave a shallow depression ready for spot fitting.

Square edged boards are designed for use with a cover strip over all joints either for a panelled effect or for demountable partitions. Wood, metal or plastic strips are nailed or glued over joints.

It is not uncommon for wallboard to be used as a base for a thin

skim coat of gypsum plaster even though the smaller baseboard is more convenient to use, particularly to ceilings.

Tapered edge boards are made for jointing with a smooth, flush finish ready for direct decoration. The shallow depression at the joint between boards is first filled with joint filler, made of gypsum and water, into which a 50 mm wide paper jointing tape is pressed. The joint is completed with filler which is finished flush with the board as illustrated in Fig. 216. Nail heads are covered with filler, finished smooth as spot filling.

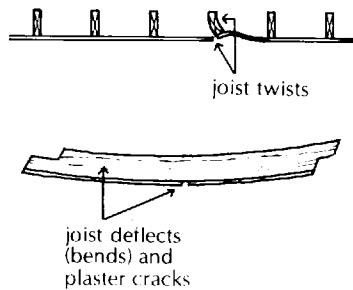


Fig. 217 Cracking in plasterboard finishes.

The principal causes of cracking in these finishes are twisting and other moisture movements of timber joists or studs to which they are fixed and deflection of timber joists under load. New timber is often not as well seasoned as it should be and as the timbers dry out they tend to shrink and lose shape. Joists may wind (twist) and cause the rigid boards fixed to them to move and joints open up as illustrated in Fig. 217. Strutting between joists will restrain movement and minimise cracking.

Under the load of furniture and persons, timber floor joists bend slightly. The degree to which they bend is described as their deflection under load. Even with very small deflection under load a large rigid plasterboard will bend and cracks appear at joints as illustrated in Fig. 217. One way of minimising cracking with large boards is to use joists some 50 mm deeper than they need be to carry the anticipated loads. This additional depth of joist reduces deflection under load and the possibility of cracking. Baseboard, made specifically for a plaster finish, is smaller than full size wallboard and may, therefore, be less liable to show cracks due to shrinkage and movement cracks.

## Gypsum baseboard

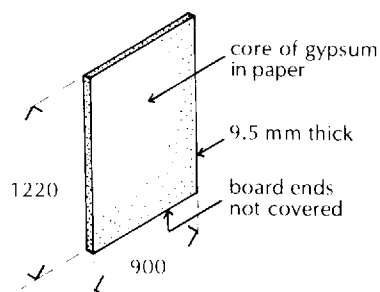


Fig. 218 Gypsum baseboard.

Gypsum baseboard is designed specifically for use as a base for gypsum plaster. The boards are 9.5 mm thick, 900 mm wide and 1220 mm long, and are chosen for use as ceiling lining for their manageable size. The boards have square edges as illustrated in Fig. 218.

The boards are fixed with 30 mm nails at 150 mm centres with a gap of about 3 mm at joints. The joints are filled with filler into which reinforcing paper tape is pressed and the boards are covered with board finish gypsum plaster that is spread and trowelled smooth to a thickness of 2 to 5 mm as illustrated in Fig. 219.

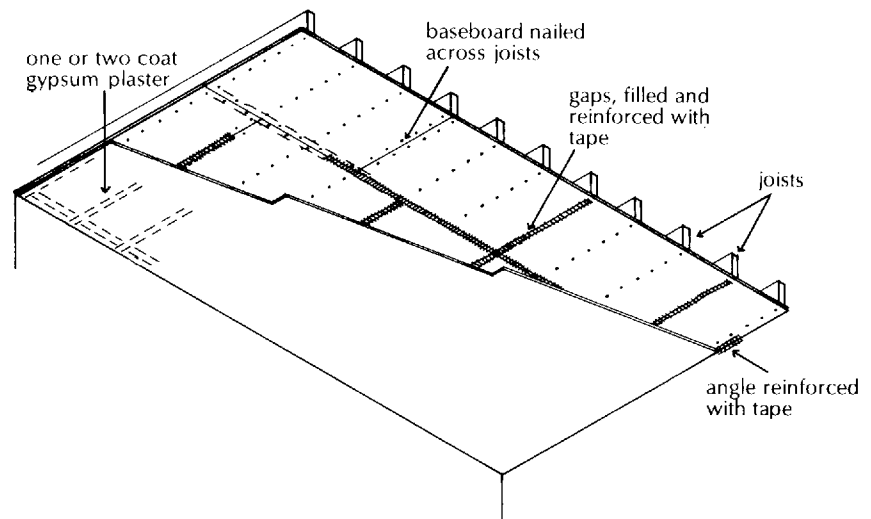


Fig. 219 Fixing baseboard for plastering.

## Gypsum plank

Gypsum plank is 19 mm thick, 600 mm wide and 2350 and 3000 mm long with either tapered edges for seamless jointing for direct decoration or square edges for plastering. This thicker board, which may be used for enhanced fire resistance or a small increase in sound insulation, may be fixed at 600 mm centres with 60 mm nails.

For direct decoration the tapered edge boards are jointed and finished as described for wallboard. For plastering the square edge boards are fixed with a gap of about 3 mm into which plaster or filler is run and reinforced with 50 mm wide paper tape. Gypsum finish plaster is then spread over the surface of the boards, levelled and trowelled to a smooth finish to a thickness of 2 to 5 mm.

## Gypsum lath

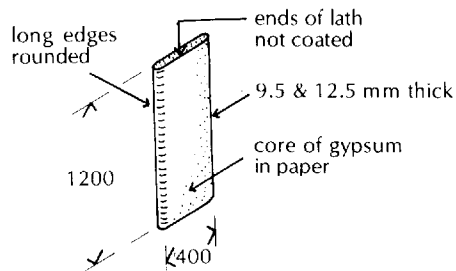


Fig. 220 Gypsum lath.

These comparatively small boards are made specifically as a base for ceiling lining for the ease of holding and fixing and as a base for plaster either as a thin skim coat or more particularly for a two coat finish. The two coat finish is preferred as the undercoat will facilitate accurate levelling over the many joints.

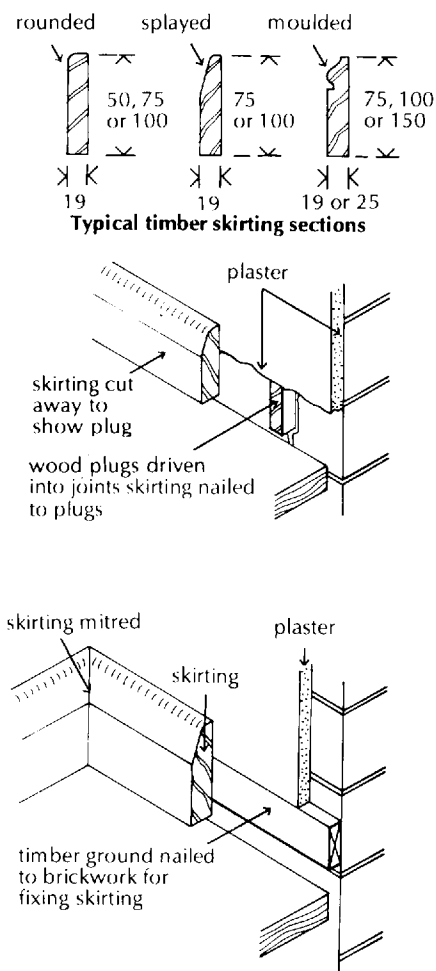
Lath is 400 mm wide, 1200 mm long and 9.5 and 12.5 mm thick. The long edges of the boards are rounded as illustrated in Fig. 220. The lath is fixed to timber joists and ceiling with a gap of not more than 3 mm between boards. The joints do not have to be reinforced with tape. The lath is covered and finished with one finish coat to a thickness of up to 5 mm or more, usually with a gypsum undercoat 8 mm thick and a finish coat of about 2 mm thickness.

The thicker board with a two coat gypsum plaster finish will provide improved resistance to fire and some increase in sound insulation.

## SKIRTINGS AND ARCHITRAVES

### Skirting

#### Timber skirting board



**Fig. 221** Fixing timber skirtings.

A skirting is a narrow band, usually projecting, formed around the base (skirt) of walls at the intersection of wall and floor. It serves to emphasise the junction of vertical and horizontal surfaces and is made from some material sufficiently hard to withstand knocks.

The types of skirting commonly used are timber, metal, tile and Magnesite.

A timber skirting is the traditional finish used at the junction of timber floors and plastered walls, to mask the junction of floor finish and plaster which would, if exposed, look ugly and collect dirt.

Soft wood boards, 19 or 25 mm thick, from 50 to 150 mm wide and rounded or moulded on one edge are generally used. The skirting boards are nailed to plugs, grounds or concrete fixing blocks at the base of walls after plastering is completed. Figure 221 illustrates some typical sections of skirting board and the fixing of the board.

Plugs are wedge-shaped pieces of timber which are driven into brick or block joints from which the mortar has been cut out as illustrated in Fig. 221. This rough method of providing a fixing is usually unsatisfactory as it is not always possible to drive the wedge into a joint without damage and it is difficult to ensure that the face of the plug finishes at the required level. Nailing into the end grain of the wood plug may not provide a secure hold.

An alternative is to nail soldiers to the wall. Soldiers are short offcuts of sawn soft wood timber 38 or 50 mm wide and the same thickness as finished plaster. The soldiers are fixed vertically at intervals of 300 to 400 mm apart as a fixing for the skirting board. Soldiers, which provide a more secure fixing than plugs, are laborious to fix.

Grounds are small section lengths of sawn soft wood timber, 38 or 50 mm wide and as thick as the plaster on the wall. These timber grounds are nailed horizontally to the wall as a background to which the skirting can be nailed as illustrated in Fig. 221. Grounds are generally fixed before plastering is commenced so that the plaster can be finished down on to and level with them.

Concrete fixing blocks are either purpose made or cut from light-weight concrete building blocks and built into brick walls at intervals of 300 to 400 mm as a fixing for skirtings.

A recently used method of fixing wood skirtings is to run wall plasters down to floor level and fix the skirting with an adhesive directly to the plaster. The contact adhesive is spread on the back of the skirting and the plaster from a hand operated cartridge gun. These adhesives provide a secure bond to plaster. With long runs of skirting it is probably wise to supplement the adhesive bond with two or more screws, driven through the skirting into plugs in the wall to resist such

## Metal skirting

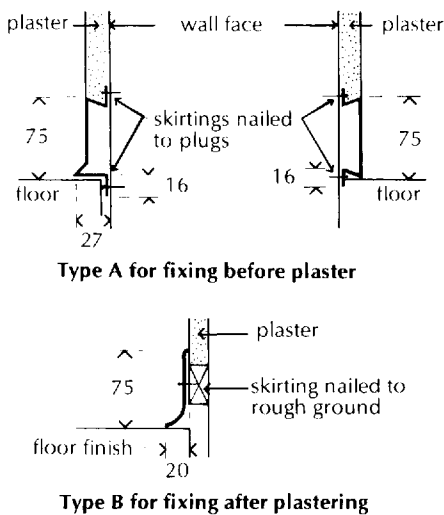


Fig. 222 Metal skirtings.

shrinkage twisting of the wood skirting that may occur and would otherwise pull the skirting from its adhesive fixing.

The traditional wood skirting was initially used to mask the joint between wall plaster and timber floor finishes where it was impossible to make a neat joint between lime plaster and boarded floors.

The more solid cement and sand and gypsum and sand undercoats and gypsum finish used today for plaster are less liable to shrinkage cracking and may be finished directly on to solid floor finishes or down on to pressed metal skirtings. These metal skirtings are used as a finish which is less liable to damage by knocks at floor level than plaster and coincide with the fashion for plain unornamented finishes such as plaster stops around door frames and linings.

A range of pressed steel skirtings is manufactured for fixing either before or after plastering. The skirting is pressed from mild steel strip and is supplied painted with one coat of red oxide priming paint. Figure 222 illustrates these sections and their use.

It will be seen that the skirting is fixed by nailing it directly to lightweight blocks or to plugs in brick and block joints or to a timber ground. Special corner pieces to finish these skirtings at internal and external angles are supplied.

These skirtings may be painted in with wall finishes or a different colour and type of paint, such as gloss or eggshell finish for the facility of cleaning by washing.

## Tile skirting

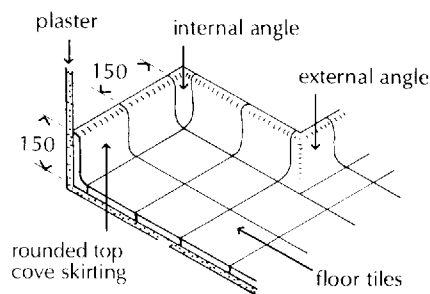


Fig. 223 Tile skirting.

The manufacturers of floor quarries and clay floor tiles make skirting to match the colour and size of their products. The skirting tiles have rounded top edges and a cove base to provide an easily cleaned rounded internal angle between skirting and floor.

The skirting tiles are first thoroughly soaked in water and then bedded in sand and cement against walls and partitions as the floor finish is laid. Special internal and external angle fittings are made. Figure 223 illustrates the use of these skirting tiles.

Skirting tiles make a particularly hardwearing, easily cleaned finish at the junction of floor and walls and are commonly used with quarry and clay tile finishes to solid floors in rooms and places where the conditions are wet and humid, such as kitchens, bathing areas and laundries. To avoid excessive condensation on smooth, hard surfaces such as tiles, they should be applied to floor and external walls surfaces that are adequately insulated.

## Magnesite and anhydrite skirtings

When solid floors are finished with one of the jointless floor finishes such as magnesium oxychloride or anhydrite it is quite usual for the material to be used as a skirting with a cove formed at the junction of

## Architrave

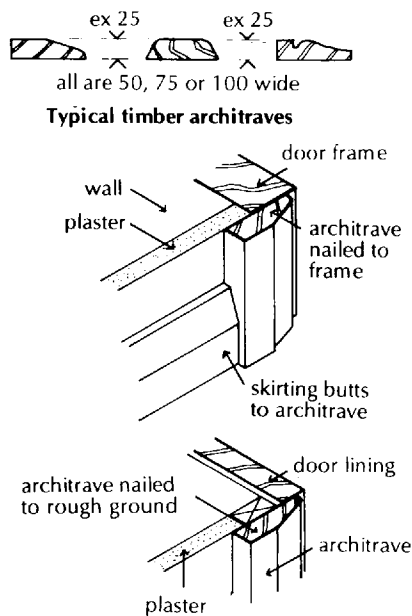


Fig. 224 Architraves.

floor and skirting. As with cove tile skirtings this makes a neat, easily cleaned finish.

The word architrave describes a decorative moulding fixed or cut around doors and windows to emphasise and decorate the opening. An architrave can be cut or moulded on blocks of stone, concrete or clay, built around openings externally. Internal architraves usually consist of lengths of moulded wood nailed around doors and windows. An internal wood architrave serves two purposes, to emphasise the opening and to mask the junction of wall plaster and timber door or window frame. If an architrave is not used an ugly crack tends to open up between the back of frames, linings and wall plaster. It is to hide this crack that the architrave is fixed.

A timber architrave is usually 19 or 25 mm thick and from 50 to 100 mm wide. It may be finished with rounded edges, or splayed into the door or decorated with some moulding. Usual practice is to fix architraves so that they diminish in section towards the door or window. Narrow architraves can be fixed by nailing them to the frame or lining of the door or window. Wide architraves are usually fixed to sawn soft wood grounds nailed to the wall around the frame or lining as a background to which the architrave can be securely nailed. Architraves are mitre cut ( $45^\circ$  cut) at angles. Figure 224 illustrates some typical sections and fixing of architraves.

As an alternative to wood architraves one of the metal, plaster stops may be used. For these to be successful in masking the joint between door linings or frames the linings and frames must be securely fixed else closing doors will cause cracks to open up.

## EXTERNAL RENDERING

Owing to their colour and texture, common bricks and concrete and clay blocks do not provide what is commonly considered to be an attractive external finish for buildings. The external faces of walls built with these materials are often rendered with two or three coats of cement and lime mixed with natural aggregate and finished either smooth or textured.

In exposed positions, walls may become so saturated by rain that water penetrates to their inside face. Because an external rendering generally improves the resistance of a wall to rain penetration, the walls of buildings on the coast and on high ground are often rendered externally.

As an applied external finish to walls as additional weather protection, renderings depend on a strong bond to the background wall, on the mix used in the rendering material and on the surface finish. The rendering should have a strong bond or key to the background wall as a mechanical bond between the rendering and the wall and so that the bond resists the drying shrinkage inevitable in any wet



applied mix of rendering. The surface of the background wall should provide a strong mechanical key for the rendering by the use of keyed flettons, raking out the mortar joints, hacking or scoring otherwise dense concrete surfaces and hacking smooth stone surfaces.

If there is not a strong bond of rendering to background walls the rendering may shrink, crack and come away from the background and water will enter the cracks and saturate the background from which it will not readily evaporate. As a general rule the richer the mix of cement in the rendering material the stronger should be the background material and key. It is idle to cover poor quality bricks with a cement-rich rendering, which will crack, let in water and make and maintain the wall in a more saturated condition than it would be if not rendered.

The mixes for renderings depend on the background wall, lean mixes of cement and lime being used for soft porous materials and the richer cement and lime mixes for the more dense backgrounds so that the density and porosity of the rendering corresponds roughly to that of the background.

The types of external rendering used are smooth (wood float finish), scraped finish, textured finish, pebbledash (drydash), roughcast (wet dash) and machine applied finish.

### **Smooth, wood float finish**

Smooth (wood float finish) rendering is usually applied in two coats. The first coat is spread by trowel and struck off level to a thickness of about 11 mm. The surface of the first coat is scratched before it dries to provide key for the next coat. The first coat should be allowed to dry out. The next coat is spread by trowel and finished smooth and level to a thickness of about 8 mm. The surface of smooth renderings should be finished with a wood float rather than a steel trowel. A steel trowel brings water and the finer particles of cement and lime to the surface which, on drying out, shrink and cause surface cracks. A wood float (trowel) leaves the surface coarse textured and less liable to surface cracks. Three coat rendering is used mostly in exposed positions to provide a thick protective coating to walls. The two undercoats are spread, scratched for key and allowed to dry out to a thickness of about 10 mm for each coat; the third or finishing coat is spread and finished smooth to a thickness of from 6 to 10 mm.

### **Spatterdash**

Smooth, dense wall surfaces such as dense brick and situ-cast concrete afford a poor key and little suction for renderings. Such surfaces can be prepared for rendering by the application of a spatterdash of wet cement and sand. A wet mix of cement and clean sand (mix 1 : 2, by volume) is thrown on to the surface and left to harden without being trowelled smooth. When dry it provides a surface suitable for the rendering, which is applied in the normal way.

### **Scraped-finish rendering**

An undercoat and finish coat are spread as for a smooth finish and the finished level surface, when it has set, is scraped with a steel straight edge or saw blade to remove some 2 mm from the surface to produce a coarse textured finish.

### **Textured-finish**

The colour and texture of smooth rendering appear dull and unattractive to some people and they prefer a broken or textured surface.

Textured rendering is usually applied in two coats. The first coat is spread and allowed to dry as previously described. The second coat is then spread by trowel and finished level. When this second coat is sufficiently hard, but still wet, its surface is textured with wood combs, brushes, sacking, wire mesh or old saw blades. A variety of effects can be obtained by varying the way in which the surface is textured.

An advantage of textured rendering is that the surface scraping removes any scum of water, cement and lime that may have been brought to the surface by trowelling and which might otherwise have caused surface cracking.

### **Pebbledash (drydash) finish**

This finish is produced by throwing dry pebbles, shingle or crushed stone on to, and lightly pressed into, the freshly applied finish coat of rendering so that the pebbles adhere to the rendering but are mostly left exposed as a surface of pebbles. Pebbles of from 6 to 13 gauge are used. The undercoat and finish coat are of a mix suited to the background and are trowelled and finished level. The advantage of this finish is that any hair cracks that may open due to the drying shrinkage of the rendering are masked by the pebble dash.

### **Roughcast (wetdash) finish**

A wet mix of rendering is thrown on to the matured undercoat by hand to a thickness of from 6 to 13 mm to produce a rough irregular textured finish. The finish is determined by the gauge of the aggregate used in the wet mix.

### **Machine applied finish**

A wet mix of rendering is thrown on to a matured undercoat by machine to produce a regular coarse textured finish. The texture of the finish is determined by the gauge of the aggregate used in the final wetdash finish which may have the natural colour of the materials or be coloured to produce what are called Tyrolean finishes.

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# VOLUME 2

## **WINDOWS - DOORS - STAIRS - FIRES, STOVES AND CHIMNEYS - INTERNAL FINISHES AND EXTERNAL RENDERING**

Since publication of the first volume of *The Construction of Buildings* in 1958, the five volume series has been used by both lecturers and students of architecture, building and surveying, and by those seeking guidance for self-build housing and works of alteration and addition.

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